

SCIENCE

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TENDENCIES OF MODERN ELECTRICAL RESEARCH.

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MODERN electrical research may be divided into two principal groups. Faraday's discoveries in electro-chemistry form the central part of the first group. The characteristic feature of the second group is Faraday's view of electro-magnetic phenomena, the view, namely, that electric and magnetic forces between material bodies act contiguously, that is from point to point through the intervening medium, the lumeniferous ether. These two groups are the foundation pillars which support the splendid edifice of the modern science of electricity. Faraday laid its foundation and he also raised the most essential parts of its splendid structure. But this structure bears to-day so many marks of the genius of Maxwell, Thomson, Helmholtz and Hertz that in our admiration for the exquisite detail which we owe to these great followers of Faraday we often forget the original design and the designer. Even so eminent a mathematical physicist as Poincaré can write profound mathematical treatises on modern electro-magnetic theory with scarcely a mention of Faraday's name.

A broad view of the tendencies of modern electrical research is obtained by comparing the fundamental concepts concerning electric and magnetic phenomena which pre-

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vail to-day to the fundamental concepts which prevailed during the period preceding Faraday. One of the most striking results which this comparison brings out is the evolutionary development of new mental concepts in the science of electricity, going on hand in hand with the accumulation of new physical facts. Faraday was a rare combination of the discoverer and the philosopher, capable of interpreting his experimental discoveries in terms of broader concepts suggested by these discoveries, enriching thus both our knowledge with new physical facts and also our mode of scientific reasoning concerning these facts with new mental concepts.

The concepts which Faraday first introduced into the Science of Electricity form the characteristic elements of the tendencies of modern electrical research. A discussion of these tendencies means, therefore, a careful analysis of these modern concepts.

The two principal elements in our ideas of physical phenomena are necessarily substance and force, that is the seat of phenomena and the agent to whose activity the phenomena are due. It is evident, therefore, that our ideas of electric and magnetic phenomena are, in a certain sense, the same to-day as they were a hundred years ago: that is, they are ideas of the electric and of the magnetic forces, and of the substances in which these forces display their activity. But although these ideas relate to the same concepts, their form to-day is vastly different from the form which they had a hundred years ago; and obviously so, because our ideas concerning forces and substances in general are much broader now than they were then.

The prototypes of our ideas of forces and substances are of course our mental concepts of mechanical force and of ponderable matter, and the Science of Mechanics is, therefore, the foundation of all exact physical

sciences. The Science of Electricity is in more than one sense an extension of the Science of Mechanics, or rather of Dynamics. To this, the oldest and formally most perfect of all exact physical sciences, the Science of Electricity owes its terminology, its definiteness, and its elevation to the level of an exact science. Necessarily so, for the most satisfactory quantitative measure of any accidental quality of matter, like electrification or magnetization, is the mechanical force which accompanies this quality. Thus the history of the Science of Electricity as an exact Science dates from Cavendish's Coulomb's and Ampère's discoveries of the law of mechanical force between electrified or magnetized substances, and between conductors carrying electric currents. The concept of force is to-day and it always was the inseparable bond of union between these two sciences. But just as the history of Mechanics is simply a record of the evolutionary development of our ideas of mechanical force, similarly the history of the Science of Electricity is the history of the continuous expansion of our views concerning electric and magnetic forces. It is owing to this expansion that an apparent emancipation of the younger science from the older has taken place.

We are becoming more and more familiar with the modern division of the Science of Physics into *Physics of Ether* and *Physics of Ponderable Matter*. A closer examination of this modern division of Physics brings us face to face with one of the most important modern scientific doctrines. This doctrine, broadly considered, states that just as the Science of Mechanics is the foundation of physics of ponderable matter, so the Science of Electricity is on the eve of becoming, if it has not already become, the foundation of Physics of Ether. The existence of this doctrine is the most forcible expression of the tendencies of modern electrical research. Such a division is not only permissible and

convenient, but even indispensable, if it is the result of our conviction that the most essential elements of electric and magnetic phenomena, that is, electric and magnetic forces and the substances which are the seat of activity of these forces, cannot be described completely in terms of the concepts of dynamics of ponderable matter. We acknowledge that such is our conviction as soon as we admit that the electric and magnetic forces are manifestations of the various states of a substance which is not ordinary matter and which, therefore, does not form a part of that past experience of ours which led to the formulation of the fundamental axioms of Dynamics. Modern electrical research believes in the existence of a substance which has the relation just mentioned to the electric and magnetic forces, and it has succeeded in identifying this substance with the lumeniferous ether; it sanctions, therefore, a temporary division of Dynamics into *Dynamics of Ponderable Matter* and *Dynamics of Ether*.

In order to approach this subject more closely, it is necessary now to state briefly how our present ideas of electric and magnetic forces developed gradually out of our ideas of ordinary mechanical forces. This is, in my opinion, the most efficient method of distinguishing between the essential and the non-essential elements of Physics of Ether. Without this distinction there is no reliable way of assigning the proper weight to the various features of the tendencies of modern electrical research.

MODERN DYNAMICS AND THE DOCTRINE OF DIRECT ACTION AT A DISTANCE.

Pressures and tensions are the oldest and most intelligible pictures of our ideas of the concept force. But there was a time when these pictures seemed to give us but one phase of this mental concept. They failed to explain the motion of machines and of projectiles, although it was recognized long

before the Science of Statics had reached its stage of perfection in which we find it nearly three hundred years ago, that in these phenomena force was an essential element. It should also be observed that there was a time when the action of a mechanical force between bodies that had no visible material connection was not suspected. Thus Thales, of Miletus, believed to have detected in the attraction of a piece of amber when electrified by friction the presence of an awakened universal soul. The attraction of a loadstone gave rise to most remarkable superstitions. Even Gilbert, the foremost physician and physicist of the Elizabethan age, suspected in the attractions and repulsions between magnets the manifestations of an occult virtue, and whenever he attempted to explain this virtue he necessarily dragged in his ideas of force as illustrated by pressures and tensions in material bodies. 'Horror vacui' and the tendency of bodies to seek their proper place were for nearly two thousand years the only explanations of the action of gravitating force. The modern concept of force as a concise statement of a law of motion was first introduced into the Science of Mechanics by the genius of Galileo Galilei in the seventeenth century. This new, so-called dynamical concept of force, discovered by Galileo as a result of his experiments on the motion of a freely falling body is really nothing more nor less than a concise statement that a freely falling body increases its vertical velocity uniformly with the time of descent, and that, therefore, we can say: the gravitational force acting upon it is constant. Lagrange speaks as follows of this discovery: "It forms to-day the permanent and the most essential part of the glory of this great man. His discoveries of the satellites of Jupiter, of the phases of Venus, of sunspots, and so forth, required telescopes and patience only; but it was a stroke of extraordinary genius to disen-

tangle a law of nature from the phenomena which men always had before their eyes, but whose explanation had nevertheless always escaped the inquiry of the philosopher."

By this discovery Galileo laid the foundation of the modern science of Dynamics. Newton completed the work so well begun; the result is summed up in the three Axioms or Laws of Motion.

Newton's discovery of the law of universal gravitation furnished a splendid illustration of the dynamical concept of force. Newton also supplemented his physical discoveries by a mathematical discovery of equal magnitude. I mean the discovery of the infinitesimal calculus. It enabled him to express the new idea of force by a mathematical formula of rare simplicity, for nothing could be simpler than the formula which states that the flux or rate of change of momentum equals the moving force. This simplicity gave to the dynamical idea of force a fresh and almost irresistible charm. The Newtonian force considered formally is a mathematical symbol, a rate of variation, or, as the mathematician calls it, a differential coefficient, and this symbol considered physically conveys to our mind nothing more than simply a description of the instantaneous state of motion. It matters little what the mechanism is by means of which the moving body receives the impulses of the force. Newton's Dynamics did not explain the mechanism by means of which material bodies gravitate toward each other, nor did it suggest any immediate need for such an explanation. The hypothesis of direct action at a distance worked just as well as any other hypothesis, and it had the advantage of settling aimless discussions quickly when the Science of Dynamics was too busy with numerous important problems awaiting solution to waste its time on needless speculation; and, besides, there were really none but

purely metaphysical arguments that could be brought in the case of gravitational force against this hypothesis of direct action at a distance.

But, unfortunately, that which at one time was looked upon as a convenient hypothesis threatened to become a fixed scientific creed. Newton's dynamics considered force in its aspect of a law of motion expressible by a simple mathematical symbol and nothing else; but just as the Greek mind saw an active divinity in every physical phenomenon, and Thales ascribed the electrical attraction of amber to the manifestation of a universal soul, and Gilbert perceived the activity of an occult virtue in a magnet, so the so-called Newtonian school ascribed an objectively active existence to the law of gravitation and called it the force of gravitation. Even more than that. To Newton the force of gravitation was something merely descriptive; to the Newtonian school of mathematical physicists it was an attribute of matter that had an objectively active existence in consequence of which matter could act upon matter directly at a distance. "It is true," says Maxwell,* "that at one time those who speculated as to the causes of physical phenomena were in the habit of accounting for each kind of action at a distance by means of a special ætherial fluid, whose function and property it was to produce these actions. They filled all space three and four times over with ethers of different kinds, the properties of which were invented merely to save appearances, so that more rational enquirers were willing rather to accept not only Newton's definite law of attraction at a distance, but even the dogma of Cotes, that action at a distance is one of the primary properties of matter, and that no explanation can be more intelligible than this fact. Hence the undulatory theory of light has met with much opposition directed not against its failure to explain phe-

* Treatise on Elec. and Mag., 2d ed., p. 448.

nomena, but against its assumption of the existence of a medium in which light is propagated." The mathematical formula which describes the law of action at a distance of a force like gravitation, electric and magnetic attractions and repulsions was, in the opinion of most mathematical physicists of the last century, the most essential element of and the ultimate goal in our knowledge of this physical concept. For if the direct action at a distance doctrine be accepted what else remains there to enquire into? How much of this scientific creed received a direct support from Newton personally is difficult to tell. One thing is certain; he gave no support to the beautiful undulatory theory of light originated by his friends, Hooke and Huyghens, and it is interesting to observe here that it was owing to the intellectual rebellion of those very men who supported the undulatory theory of light of Hooke and Huyghens against Newton's corpuscular theory that the belief in direct action at a distance began to lose ground.

UNDULATORY THEORY OF LIGHT AND THE
DOCTRINE OF DIRECT ACTION AT
A DISTANCE.

There is one aspect of the Undulatory Theory of Light which, in my opinion, deserves much more attention than is generally devoted to it. This theory gave expression to a current of thought which ran diametrically opposite to the direct action at a distance doctrine of the Newtonian school. For we should observe here that the development of Newtonian dynamics of rigid bodies was accompanied by a steady though somewhat less rapid progress of the dynamics of compressible and incompressible fluids and of compressible solids, that is the Sciences of Hydrodynamics and of Elasticity. Now, Hydrodynamics and Elasticity consider more particularly the modern extension of our original statical concept of force, that is, force

considered as a pressure, a tension, or as a stress of any kind in a continuous material system in which each part, no matter how small, is capable of a relative displacement with respect to the adjacent parts, each such displacement being accompanied by an elastic reaction having a perfectly definite relation to the displacement. This relation cannot be found by abstract reasoning based on the concepts of Statics or on those contained in the Newtonian axioms, but must be determined by actual experiment. Observe now that Hooke, one of the earliest investigators in this experimental field, was one of the founders of the Undulatory Theory of Light. Hydrodynamics and Elasticity containing as they do an additional experimental element mark an advance in our physical knowledge of force and substance over that contained in the Newtonian axioms. The most important element in this advance is the recognition of the very important physical fact that matter is capable of propagating force between the various parts of a continuous material system with a perfectly definite velocity and in a perfectly definite manner, both the velocity and the form of propagation, *that is, the form of the wave*, depending not only on the distribution of the masses of the system, but also on the elastic property of each elementary mass. Hence, whereas the so-called Newtonian school of physicists, influenced by the many unsuccessful attempts to explain gravitational force by mechanical hypotheses, considered force principally in its formal or mathematical aspect and also in aspect of an objectively active property of matter, capable of acting directly at the distance, there was another school of physicists, with Hooke and Huyghens at its head, who focused their attention upon just the opposite aspect of force, that is, force considered as a state of stress, and hence incapable of being communicated from one

body to another, unless there is a material connection between them. It is this view of force which led to the formulation of the Wave Theory of Light; it is also this view of force which gives us the nearest physical picture of the modern view of electric and magnetic forces. But the view of electric and magnetic forces which prevailed during the last century and during the first part of this century was that which accorded with the scientific credo of the Newtonian school. This is easily accounted for. The successful solution of many most remarkable dynamical problems, like the theory of tides, the figure of the earth, the problem of planetary perturbations, etc., commanded most profound attention. They were just so many signal triumphs of Newtonian dynamics and of the Newtonian school. No one dared to doubt the infallibility of anything that *seemed* to have even the remotest connection with Newton's philosophy. The laws of action of Electric and Magnetic forces, that is, the laws of Cavendish, Coulomb and Ampère, all followed the rule of the inverse square of distance and resembled, therefore, Newton's law of gravitation in a most remarkable manner. It is, therefore, not at all surprising that the doctrine of direct action at a distance, which *seemed* to have done so much good in the theory of gravitation, should have been transferred bodily into Science of Electricity and Magnetism.

But the victory of the Undulatory Theory of Light, revived by Young and Fresnel, over the corpuscular theory lessened considerably the confidence in Newton's unquestioned authority and in the correctness of the doctrines of the so-called Newtonian school. Besides, this Undulatory Theory brought into conspicuous prominence a new form of matter which was independent of that mysterious attribute, the gravitating force that acts directly at a distance; a substance permeating all space, even the

innermost interstices of ponderable matter, and capable of transmitting actions between material bodies with enormous velocity. Add to this the invention of the steam engine and the discovery of the galvanic cell, the operations of which had no apparent immediate connection with any formal laws of Newton's dynamics or with Coulomb's and Ampère's distance laws of electric and magnetic force and the scientific atmosphere at the beginning of this century will appear to us in its true light, that is, full of indications that the arrival of a new physical truth was near, a truth which was not explicitly stated in Newton's dynamics and which to be fully appreciated by the human mind needed a new physical concept there, the concept of *energy*. The age which saw the arrival of the Undulatory Theory of Light and of the Principle of Conservation of Energy was worthy of the honor of being the age in which Faraday lived.

FARADAY'S RESEARCHES.

When Faraday entered the field of electrical research, that which he found there worthy of the name of an exact science were Coulomb's, Cavendish's and Ampère's laws of force of inverse square. The method of analyzing electric and magnetic phenomena which prevailed at that time is well illustrated in Poisson's theory of induced magnetism, "who," and here I quote Maxwell, "by following the path pointed out by Newton and making the forces which act between bodies the principal object of study, founded the mathematical theories of electric and magnetic forces."

The field of Electrical Science, view it as you may, was narrow when Faraday entered it. Besides, the old superstition of direct action at a distance surrounded it on every side like a Chinese wall. There seemed to be no exit, no communication with the outside world of science where Faraday saw wide fields of activity opened

up by the Undulatory Theory of Light and the Principle of Conservation of Energy, with both of which his mind was thoroughly imbued. Electric and magnetic attractions and repulsions between material bodies, induced electrifications and magnetizations and the manner in which these actions between material bodies were modified by a change of the medium separating them—all these phenomena could not fail to reveal to a bold investigator of Nature's hidden laws, like Faraday, that the law of inverse square is by no means the final goal of inquiry concerning electric and magnetic forces. The many failures to pass beyond that goal in the case of gravitational force did not discourage him.

It is far beyond the limits of this brief discussion to give an adequate review of Faraday's epoch making discoveries by means of which the Electrical Science was liberated from its hopeless prison of direct action at a distance theories and started on its new and eventful career. Suffice it to mention briefly the main features only of these discoveries, in order to bring out as forcibly as I can their bearing upon the tendencies of modern electrical research.* Faraday's discoveries are generally known to-day through the technical applications of the fundamental principles which were first established by these discoveries. The dynamo and the motor, the telegraph and the telephone, the induction coil and the modern transformer, all these great inventions, in fact, the whole science of electro-magnetic induction, both pure and applied, are only single illustrations of the wide range which is covered by these discoveries. But it is no more than just to mention here that in the region of electromagnetic

induction a very fair, if not an equal, share of the glory of original discovery belongs to our own countryman, illustrious Joseph Henry.

Faraday can well afford to share these honors with so great a physicist. For it adds to his greatness to have it recorded in the annals of science that the supreme effort in the life work of so great a physicist as Joseph Henry was the first step only in the long series of Faraday's far-reaching discoveries. The phenomena of electro-magnetic induction seem to have absorbed the smallest part of Faraday's attention during the earliest period of his electrical researches, and the question which presents itself to every thoughtful student of Faraday's 'Experimental Researches' is: What called Faraday away so soon from this important and promising field? For who does not feel that the pleasure one gets from reading Faraday's masterly story of his discoveries in electro-magnetic induction, given in the first part of Volume I. of his 'Researches,' ends much too soon? I even venture to suggest that many a one among the students of Faraday, whose taste runs more in the direction of estimating the value of a new discovery by the immediate practical application to which it can be put, has undoubtedly bemoaned the fact that Faraday allowed himself to be drawn away so soon from his researches in electro-magnetic induction to matters so abstract as electro-chemistry, electric discharges through gases, specific inductive capacity of dielectrics, magneto-crystalline action, magnetic properties of flames and gases, action of magnetism on light, etc.

But a careful review of Faraday's long series of researches suggests a very intimate connection between the numerous and apparently independent parts of that series. They are all just so many tributary streams which flow into the same main

*The substance of the following summary of Faraday's discoveries and their aim was given by the author in 1894 in the *Electrical World* in a series of articles entitled 'The Faraday-Maxwell-Hertzian epoch.'

current of thought. This current starts from the phenomena of electro-magnetic induction. The tributary streams make it stronger and stronger. It grows wider and wider, and finally as if expanding beyond the limits of our mental vision disappears in the dim regions, which, according to Faraday's surmises, connect the phenomena of light, electricity, and magnetism. The phenomena of electro-magnetic induction inspired the prophetic mind of Faraday with the belief that there must be an invisible mechanism connecting material bodies, and that it is the activity of this mechanism which makes us cognizant of the existence of electric and magnetic forces. He gave expression to this belief by introducing into his mode of thought and of description a new term, the term magnetic curves or lines of magnetic force. At first he gave us only their geometrical definition. "By magnetic curves," he added in a footnote, Volume I., page 32, "I mean the lines of magnetic force, however modified by juxtaposition of poles, which would be depicted by iron filings; of those to which a very small magnetic needle would form a tangent." But the intimate connection between the phenomena of electro-magnetic induction and these curves, or lines of magnetic force, convinced him that these curves had an actual physical existence and that they were not mere geometrical space relations, of which the iron filings give us a convenient material picture. He seemed to be aware that the nature of these new physical existences could not be revealed by a study of phenomena like those of electro-magnetic induction, as long as these phenomena could be observed in bodies of finite dimensions only, and this being the case then he would naturally expect that the road leading to the understanding of the lines of force was by way of the phenomena which can be traced with certainty to the ultimate elements of mat-

ter, to atoms and molecules. This would have been the voice then which called Faraday away from his researches in electro-magnetic induction and bade him rise higher and higher until he reached heights so lofty that only a genius like that of Maxwell could reach him. This is, I venture to suggest, why Faraday's discoveries in electro-magnetic induction led him into researches of what may be called the atomic and molecular region of the science of electricity. From this point of view, the chronological order appears quite natural in which his researches in electro-chemistry, voltaic electricity, specific inductive capacity of dielectrics, disruptive discharges through gases, animal electricity, action of magnets on light, on metals and their compounds, on gases, on crystals, etc., follow each other in rapid succession. The numerous discoveries revealed by these profound researches convinced the great philosopher that his work was in the right direction. With steady aim he forced his difficult journey ahead with giant strides. The most vigorous years of his life were consumed in gathering a vast amount of evidence with which to reveal before our eyes the physical nature of the lines of force, his first inspiration, and banish the old superstition of direct action at a distance. With renewed vigor he returned to this favorite subject toward the closing years of his life. His research 'On the Lines of Magnetic Force; Their Definite Character, and Their Distribution Within a Magnet and Through Space' (Philosophical Transactions, 1852, page 1), given in the twenty-eighth series of his 'Researches,' mark the beginning of the last epoch of his great work. It prepares us to enter into Faraday's innermost thoughts and see that inspiration and those visions which guided his steps for twenty years. The essays which now follow, 'On the Lines of Magnetic Force,' 'On the Physical Character of the Lines of Magnetic

Force,' 'On the Physical Lines of Magnetic Force,' 'Thoughts on Ray Vibrations,' etc., are just like the glow of an approaching sunrise. The fairyland of Faraday's vision begins to appear clearer and clearer in this gently rising light; but, alas! the cloud of old age hides away the beauties of the sunrise itself.

It was reserved for Maxwell to raise the lofty edifice from which we first obtained a clearer view of the wonderland of Faraday's vision.

I cannot do better than sum up this brief statement of the position which, in my opinion, Faraday occupies in the tendencies of modern electrical research, by quoting the following words of Hertz,* the most brilliant of all the pupils of Helmholtz, Maxwell and Faraday: "Faraday heard of the belief that electrification puts something into a body, but he saw that the changes produced were all external and none internal. Faraday was taught that forces jump through space, but he saw that these forces were influenced in the highest degree by the substances which filled the space. Faraday read that electricities certainly existed, but that their forces were a disputed question, and yet he saw that these forces produced tangible effects, although he could not perceive anything of the electrifications themselves. Hence, in his conception, the state of these things became reversed. The electric and the magnetic forces appeared to him as existing, as real, as tangible; electricity and magnetism were things whose existence might be a disputed question. The lines of force, as he called the forces considered as independent entities, stood before his mind's eye as conditions in and of the space, as stresses, as vortices, as fluxes, as something or another

—he could not tell as what—but there they stood, influenced each other, they pushed the bodies and they pulled them, and they continued from point to point, conveying impulses to each other. The objection that nothing but absolute rest was possible in empty space he met with questions: Is space really empty? Does not light itself compel us to assume it as filled? Could not ether which conveys the waves of light become the seat of those changes which we recognize as electric and magnetic forces? Is it not even possible to imagine a relation between these changes and those waves of light? Why could not these waves of light be something like the oscillations of those lines of force?"

"So far did Faraday reach in his conceptions and his surmises. He could not prove them. He busily searched for evidences. The connection between light, electricity and magnetism was the favorite subject of his research. The beautiful connection which he found was not the one for which he looked. Only the highest old age put an end to his efforts."

MAXWELL'S INTERPRETATION OF FARADAY.

Faraday did not form a new school of physicists during his lifetime. His ideas were too original, his view of the electromagnetic phenomena was too different from the generally accepted view of his time, to gain him a large following even among his own countrymen. His generation recognized the value of his discoveries; it failed to appreciate the full meaning of the aims of his speculation. It was reserved for the next generation to grasp this meaning and to explain it in terms of the language of the existing theories. It was by no means an easy task for the next generation to perform. It required a peculiarly constituted mind, a mind combining in itself the qualities of a physical investigator and those of a mathematician. Maxwell was a true

* Vortrag, gehalten bei der 62. Versammlung deutscher Naturforscher und Aerzte zu Heidelberg am 20. September, 1889. Publ. by E. Strauss in Bonn.

representative of this rare combination. When his attention was first drawn to Faraday's work he was fortunately still out of the hearing distance of the seductive voice of the old 'direct-action-at-a-distance-theories.' I say fortunately, for, as Hertz* observed once in his characteristic way, "he who once strayed into the magic circle of these remained a captive there." Maxwell was born in June, 1831. Faraday announced his first discovery in magneto-electric induction in November of the same year. William Thomson, now Lord Kelvin, was then only ten years old, "Before I began the study of electricity," says Maxwell,† "I resolved to read no mathematics on the subject till I had first read through Faraday's 'Experimental Researches on Electricity.' I was aware that there was supposed to be a difference between Faraday's way of conceiving phenomena and that of the mathematicians, so that neither he nor they were satisfied with each other's language. I had also the conviction that this discrepancy did not arise from either party being wrong. I was first convinced of this by Sir William Thomson, to whose advice and assistance, as well as to his published papers, I owe most of what I have learned on the subject."

Maxwell was barely twenty when he first took up the study of Faraday. Sir William Thomson was twenty-four when he first announced, in 1845, in a paper 'On the Elementary Laws of Statical Electricity' (papers on 'Electrostatics and Magnetism,' Article II.), his strong inclination toward the view of Faraday. But Thomson played at that time too prominent a part in the establishment of the Principle of Conservation of Energy and the Mechanical Theory of Heat to allow Faraday's splendid discoveries to occupy his at-

tention completely. Maxwell threw his whole young heart and soul into the study of Faraday's 'Experimental Researches.' It was only a year after he took his degree at Cambridge when his first essay 'On Faraday's Lines of Force'* appeared. This essay and his second essay on the same subject, 'Physical Lines of Force,'† are the forerunners of his great memoir 'On a Dynamical Theory of the Electromagnetic Field.'‡ In his 'Treatise on Electricity and Magnetism'§ the views elaborated in these essays are presented in a somewhat different form and compared to the views of some of the older theories. 'The lines of force,' quoting the words of Hertz, 'as Faraday called the forces considered as independent entities stood before his mind's eye as conditions in and of the space, as stresses, as vortices, as fluxes, as something or another * * .' The first problem, therefore, which confronted Maxwell in his undertaking to express Faraday's views in terms of the terminology of the accepted mathematical theories at that time was evidently this: What is the physical constitution of the medium whose conditions of stress and of motion manifest themselves as electric and magnetic forces, that is, as lines or tubes of electric and of magnetic force? The first and the second essay give strikingly original mechanical pictures illustrating the properties of the medium which will fulfill most of the essential requirements. It would lead us too far to enter into a discussion of the beautiful mechanical models which represent Maxwell's earliest attempts to explain Faraday's view of the activities going on in an electromagnetic field. A popular account of this phase of Maxwell's work will be found

* Cambridge Phil. Transact., Dec. 10, 1855.

† Philosoph. Mag., March, April and May, 1861; Jan., Feb. 1862.

‡ Royal Soc. Transact., Oct., 1864.

§ Clarendon Press, Oxford, 1873.

* 1. c.

† Treatise on Electricity and Magnetism; preface, p. ix.

in Prof. O. Lodge's charming book on 'Modern Views of Electricity.'* Suffice it to state that these mechanical models were temporary structures only, as it were, mere scaffolding, which Maxwell tore down as soon as the building which he started to raise reached its completion.†

In the third essay the description of the physical properties of the medium is not so specific as in the first two. The mechanical models are replaced by broad mechanical hypotheses.

"It appears, therefore," says Maxwell, in the introduction to the famous third essay, "that certain phenomena in electricity and magnetism lead to the same conclusion as those of optics, namely, that there is an ætherial medium pervading all bodies, and modified only in degree by their presence; that the parts of this medium are capable of being set in motion by electric currents and magnets; that this motion is communicated from one part of the medium to another, by forces arising from the connections of those parts; that, under the action of these forces, there is a certain yielding depending on the elasticity of these connections, and that, therefore, energy in two different forms may exist in the medium, the one form being the actual energy of motion of its parts, and the other being the potential energy stored up in the connections, in virtue of their elasticity."

This paragraph contains the keynote of the essay. Its meaning may be illustrated in a simple manner, as follows: Consider a charged Leyden jar. Its energy is potential and stored up in a sort of elastic deformation of the dielectric, principally in that part of the dielectric which separates the metallic plates of the jar. Connect the two plates by a conducting wire; a current is set up and a magnetic field accompanying this current appears. Magnetic force is

due, according to Maxwell's mechanical hypotheses, to some kind of motion in the medium, and, therefore, the appearance of the magnetic field means that the discharging process in the jar consists in a transformation of the potential energy of the charge into kinetic energy of the magnetic field. At the moment when the jar is completely discharged, all the potential energy of the charge, except that part which has been transformed into heat in the conducting wire, appears as kinetic, that is, as magnetic energy of the field. From that moment on, this kinetic energy begins to diminish, because, owing to the peculiar connection of the conducting wire to the moving parts of the medium, the current in it will persist and charge the jar in the opposite sense, which means a retransformation of the magnetic energy of the field into the potential energy of the charged jar, and so on. These cyclic transformations continue until the total initial energy of the charged jar is transformed into heat in the conducting parts of the system. *We have electric oscillations.* These oscillations were observed by Joseph Henry, nearly twenty years before Maxwell wrote his famous third essay; Sir William Thomson discussed their theory in 1853, and Feddersen subjected this theory to crucial experimental tests from 1857 to 1862. But that which, in the estimation of the tendencies of modern electrical research, is the most essential element in our physical view of these oscillatory phenomena is entirely absent from these early investigations. Maxwell, guided by the visions of Faraday, was the first to introduce this element. It is this. If the forces of the electromagnetic field are due, as Maxwell assumed and illustrated by mechanical models, to the reactions of the moving parts of the field, elastically connected to each other, then, since these reactions must necessarily consume time in passing from any part of the field to any

* Published by Macmillan & Co.

† Treatise, Vol. 2, p. 427, 2d. ed.

other, it is evident that in the case of the oscillatory discharge of the Leyden jar, which we have just considered, the oscillatory current in the conducting wire must be accompanied by oscillatory variations of the electric and magnetic force at every point of the field, and that these oscillatory variations are propagated *with a finite velocity and in complete accordance with the laws of propagation of waves through an elastic solid.*

This is the new element which Maxwell introduced into our view of the oscillatory phenomena of electromagnetism, and it is the very heart and soul of the modern electromagnetic theory. Suppose now that these variations are very rapid, and that by a suitable detector of the electric or of the magnetic force we actually detect these waves and measure their length, then the ratio between this length and the period of oscillation will give us the velocity of propagation. Maxwell predicted that this velocity is the same as that of light of the same wave length, but he never told us how to produce these waves nor how to measure their length. In fact, he never mentioned a word about the oscillatory discharges of a Leyden jar, and without a complete understanding of these there *seemed* to be no way of getting at Maxwell's full meaning.

Referring to the theory of these oscillations Mr. O. Heaviside remarks: "It had been given by Sir W. Thompson in 1853, but it is a singular circumstance that this very remarkable and instructive phenomenon should not be so much as mentioned in the whole of Maxwell's treatise, though it is scarcely possible that he was unacquainted with it; if, for no other reason, because it is so *simple* a deduction from his equations. I lay stress on the word *simple*, because it is not to be supposed that Maxwell was fully acquainted with the whole of the consequences of his important scheme." (Electr. Papers, Vol. II., p. 83). The omission is certainly puzzling, but it can hardly be as-

sumed to furnish any evidence, as Mr. Heaviside seems to infer, that Maxwell was not fully acquainted with the whole of the consequences of his theory. For when one sees as clearly as Maxwell certainly did that the waves of light are the same thing as the electric waves, accompanying the oscillations of a Leyden jar discharge, he can well afford to ignore these and pass on without delay to the discussion of the luminous waves considered as electric waves. This was the ultimate aim of what Mr. Heaviside calls Maxwell's 'important scheme.' From a practical, and what one might call a business point of view, it must, of course, be admitted that Maxwell would have promoted much more rapidly his 'important scheme' if he had elucidated it first by the oscillations of a Leyden jar discharge, and this omission is, in a sense, a mark of incompleteness in Maxwell's presentation of Faraday's view of electromagnetic phenomena.

This unfinished part of Maxwell's monumental work remained practically just as Maxwell left it for over twenty years until, in 1887, the genius of Hertz, of Karlsruhe, completed the magnificent structure in a manner quite worthy its original designer. The existence of electric waves accompanying a Leyden jar discharge and their finite velocity of propagation, equal to the velocity of light, was demonstrated by Hertz in a series of brilliant experiments whose parallel one would seek in vain outside of Faraday's 'Experimental Researches.' They revealed to us for the first time the whole view of the electro-magnetic phenomena as they appeared to Faraday and Maxwell; they convinced us that the doctrine of direct action at a distance has no place in these phenomena; and they also inspired us with a hope that our view of the phenomena of gravitation may, perhaps, some day be liberated from the narrow prison walls of this persistent doctrine.

Hertz's contribution to Maxwell's work

did much to make that work what Maxwell intended it to be, that is, an interpretation of Faraday. "If by anything I have written," says Maxwell, "I may assist any student in understanding Faraday's modes of thought and expression, I shall regard it as the accomplishment of one of my principal aims—to communicate to others the same delight which I have found myself in reading Faraday's *Researches*." It is in this sense only that the Hertizian experiments mark a completion of what Maxwell had apparently left undone. They enable us to understand more clearly Faraday's modes of thought and expression, because they supplied the force and the vigor of living experiment where many a physicist saw formerly nothing but the inhospitable realms of what, to many of us, appear as dead symbols only of Maxwell's intricate mathematical analysis; and, above all, they revealed to us the beautiful simplicity of the loftiest among the many lofty conceptions of Maxwell's electro-magnetic theory, that is the 'Electro-magnetic Theory of Light.'

"The connection between light, electricity, and magnetism," says Hertz, "was the favorite subject of his (Faraday's) research." The same statement applies to Maxwell. *The Electro-magnetic Theory of Light is the crowning effort of his immortal work.* The fundamental idea in Maxwell's many-sided view of the phenomena of electricity and magnetism is undoubtedly the idea that the same fundamental laws govern the phenomena of electricity, magnetism and light. To formulate these laws was the ultimate problem of his great work, and when he found its solution it mattered little whether he could or could not devise a logically clear and consecutive course of analysis which would lead others to the same result. Hence the complaint on the part of mathematical physicists,* trained in

* The French school of the mathematical physicists

the school of Euclid, Newton and Ampère, because they miss in Maxwell that perspicuity and logical sequency which we all admire so much in the writings of the mathematical school of the last century. The fundamental laws of Maxwell's electro-magnetic theory, capable, as they are, of explaining not only the phenomena of electricity and magnetism, but also the phenomena of light—these laws are the building which Maxwell proposed to raise on the foundation of Faraday's discoveries and conceptions, the various mechanical hypotheses, on the other hand, concerning the physical properties of the medium which enabled him to carry out his plan in accordance with a predetermined design—these hypotheses are mere scaffolding, which can and must now be taken away if it obstructs our view of the finished building.

It is well to quote here several passages from an essay in which Hertz discussed this matter in his characteristically profound way.* "And now, to be more precise, what is it that we call the Faraday-Maxwell theory?" * * * * "Many a man has thrown himself with zeal into the study of Maxwell's work, and even when he has not stumbled upon unwonted mathematical difficulties has nevertheless been compelled to abandon the hope of forming for himself an altogether consistent conception of Maxwell's ideas. I have fared no better myself. Notwithstanding the greatest admiration for Maxwell's mathematical conceptions, I have not always felt quite certain of having grasped the physical significance of his statements." * * * * "To the question, 'what is Maxwell's theory?' I know of no shorter or more definite answer than the

seems to be especially displeased. One has only to refer to the writings of Poincaré, Bertrand, Duhem, etc., to prove the correctness of this statement.

* Electric Waves, translation by D. E. Jones, p. 20, B. Theoretical.

following: Maxwell's theory is Maxwell's system of equations.* Every theory which leads to the same system of equations, and therefore comprises the same possible phenomena, I would consider as being a form or special case of Maxwell's theory. * * * *"

Boltzman, one of Maxwell's most sincere admirers, introduces his lectures on Maxwell's electro-magnetic theory† with the following verse from Goethe's Faust, which he paraphrased evidently with the intention of describing the desperate state of his mind:

So soll ich denn mit saurem Schweiss
Euch lehren, was ich selbst nicht weiss.

MAXWELL'S ELECTRO-MAGNETIC THEORY OF LIGHT.

These statements, coming, as they do, from so high authorities, do not seem to present a cheerful outlook to those who, like myself, take upon themselves the burden of the ponderous task of popularizing Maxwell's electro-magnetic theory. But the outlook is really not quite as gloomy as it appears at first glance, provided, of course, that one limits himself to the essential parts of Maxwell's story and leaves out the ornamental detail. In other words, the story of what Maxwell actually accomplished can be told in a few and simple words; what he probably attempted to do, but did not accomplish, is a different matter and does not concern us at present. Maxwell's electro-magnetic theory in its simple form and divested of all unnecessary hypotheses can be described briefly as the extension of the meaning of certain well established experimental facts. To state these facts it is well to consider briefly the following well-known experiments:

First: Connect two metal plates, facing each other and forming an electric con-

* What Hertz calls 'Maxwell's system of equations' means the same thing as the expression 'fundamental laws,' mentioned above.

† Vorlesungen über Maxwell's Theorie, etc., publ. by Barth, Leipzig.

denser, to the poles of a galvanic cell. A transient current takes place whose value can be determined experimentally. Experiment tells us that this transient current is proportional to the electromotive force of the cell, so that n equal cells in series will produce n times the transient or integral current. Having charged the condenser we disconnect the cells and then join the plates by a conducting wire and discharge; the integral discharge current is just as large as the charging current, but in *opposite* direction. A charged condenser is, therefore, the seat of an electromotive force acting in opposite sense to the charging electromotive force. The old view maintained that this electromotive force is due to the accumulated electricities in the plates; the Faraday-Maxwell view denies this and maintains that the electromotive force is due to an action of the dielectric separating the plates. According to the old theories the current is a process confined to the conducting parts; in our present case, for instance, it is along the conducting wire and stops at the boundary separating the condenser plates from the dielectric. According to the Faraday-Maxwell view this process continues through the dielectric, and whereas it generates heat in the conducting parts it stores up energy in the dielectric just as a compression stores up energy in the body which is being compressed. The charging cell supplies the action and the dielectric reacts; *the work against this reaction is the energy of the charged condenser, which is, therefore, in the dielectric and not on the surface of the plates, as the old theories supposed.* The charging process or current continues until the electromotive reaction of the dielectric is equal to the electromotive force of the cell, and since the integral current is proportional to the electromotive force of the charging cell it follows that the electromotive reaction of a charged condenser is also proportional to

this integral current. Whatever is true of the condenser as a whole is true of any elementary part of the dielectric. Hence, whenever a current passes through any part of a dielectric it produces there a change of state which we call polarization and a consequent electromotive reaction which is proportional to the total current that has passed through. This total current Maxwell calls total electric displacement, selecting this name evidently for the purpose of bringing out the strong resemblance of the relation just described to the relation between the elastic compression of a material body and the elastic reaction produced thereby. The electric displacement depends also on the nature of the dielectric. Thus, the integral current between the same plates and acted upon by the same cell will be greater if the plates are separated by glass than if the intervening space is a perfect vacuum. The ratio between the two is the specific inductive capacity of the glass. This constant is within wide limits independent of the charging electromotive force and it corresponds to the elastic constant in elasticity. We have, therefore, summing up these relations, the following law of electric displacement or flux :

"Intensity of electromotive reaction in any direction equals the intensity of electric flux in that direction divided by the specific inductive capacity."

Second: A magnetized bar of iron is magnetically polarized just as the dielectric separating the plates of a charged condenser is electrically polarized. The resemblance between the two states is complete. We can speak, therefore, of a magnetic flux or displacement, just as we speak of an electric displacement, and experiment tells us that the first follows the same formal law as the second, viz:

Intensity of magneto-motive reaction in any direction equals the intensity of mag-

netic flux in that direction divided by the magnetic specific inductive capacity or permeability.

It should be observed that no assumption is made that these two physical constants of the medium are the same in every direction. In an allotropic substance they can, and generally will, be different in different directions.

The last law is not rigidly true for conductors of high permeability like iron, nickel, cobalt, bismuth, when the magnetizing force is high. The same limitation exists in the deformation of elastic bodies when the deformation passes beyond the elastic limit. It is not a serious limitation as long as we keep, as we necessarily do in experimental investigations of electric oscillations, within the limits of what may be called the elastic limit of electrification and magnetization.

These two laws describe one of the two essential elements in our modern view of the electric and the magnetic force, that is the view of these forces considered as reactions of the dielectric against the continuance of an abnormal condition produced in consequence of a certain process, called in one case the electric and in the other the magnetic current, having taken place there. These reactions suffice to explain the attractions and repulsions between electrified and magnetized substances, which now appear not as direct actions at a distance, but as a consequence of a definite distribution of reactions in the dielectric separating the bodies under consideration. These laws of electric and magnetic flux occupy in the modern electro-magnetic theory the same position and have the same physical significance as the laws of elasticity in mechanics of a material body. This very important element, we may call it the statical element, our modern view of the electric and magnetic force was first clearly brought out by Maxwell. His failure to illustrate it in a

completely satisfactory manner by a mechanical model is of no material consequence as far as the correctness of the laws of flux and the definiteness of our ideas of this *statical element* of electric and magnetic force is concerned.

We now come to the second essential feature of Maxwell's theory. It deals with what may be called the dynamic element of our modern ideas concerning electric and magnetic force. Oersted discovered that a conductor which is the seat of that progressive process which we call an electric current is accompanied by magnetic forces which are present in every element of the space surrounding the conductor. Ampère formulated the law in accordance with which this force is distributed in space. This law can be stated broadly as follows :

The magneto-motive force around the boundary line of any elementary area is proportional to the electric current, or what is the same thing, to the rate of variation of the electric flux through that area.

This law is one of the fundamental laws of the Faraday-Maxwell theory, but although its form is essentially the same here as it was in the old theories its meaning is very much more comprehensive. In the old theory the magneto-motive force around the boundary of any elementary area through which no conduction current passes is *always* zero. According to the new view the current is not confined to conductors, but extends to the dielectric and its value through any elementary area is equal to the rate of variation of the electric flux or integral current through that area. The law of magneto-motive force just mentioned applies to this current just as well as it does to currents in conductors. Again, in the old theory the magnetic force accompanying an electric current was a direct action at a distance between the various elements of the conductor carrying the conduction

current and a magnetic pole ; according to the new theory the magnetic force at any point of the medium is the same in this case as in any other, that is, a magneto-motive reaction in the medium produced by the integral magnetic current, that is, by the magnetic flux or induction, which was set up in the medium while the electric currents in the various parts of the field increased from their zero value to the value which they have at the moment under consideration. It must be observed, however, that since in the law just mentioned the magnetic force figures as a *rate of change of the electric flux*, that this law presents to us the dynamic element of the magnetic force just as Newton's second law of motion presents to us the dynamic element of the mechanical force.

We proceed now to consider a similar aspect of the electric force. Any change in the electric currents brings with it a change in the integral magnetic currents in the various elements of the field, and hence it implies work against the magneto-motive reactions in those elements. Hence, every electro-motive action tending to change the electric currents in any part of the field experiences a reaction to which every element of the field contributes its definite share, just as a change in the motion of any part of a mechanism is accompanied by a reaction to which every other part contributes its definite amount. How does this reaction against a change of the electric current manifest itself? The answer to this momentous question was first given by Faraday when he discovered the magneto-electric induction. This discovery can be described as follows:

Consider a loop of a conducting wire and a magnet, in its vicinity. A change of relative position of the two produces a current in the loop. If the magnet is an electro-magnet, and if we keep the relative position unchanged and change the strength of the

magnet, a current will also be induced in the loop. Again, leaving everything unchanged and changing the shape of the loop only a current will result. In each case the magnetic flux through any surface bounded by the loop is varied, and this variation of the flux produces, according to Faraday's researches, an electro-motive force in the loop. The law connecting the two may be stated as follows:

The electro-motive force around the boundary line of any elementary area is proportional to the magnetic current, or, what is the same thing, to the rate of variation of the magnetic flux through that area.

This law is the fundamental law of the Faraday-Maxwell theory which describes the dynamic element in our view of the electric force. Although the form of this law is essentially the same here as it was in the old theories its meaning is radically different. The old theories believed that unless the boundary line mentioned above consisted of a conductor, no electro-motive force around this boundary would be called into play by the variation of the magnetic flux. In the modern theory this limitation is removed. The current in the loop produced by the variation of the magnetic flux is an evidence that electro-motive reactions are set up in the dielectric surrounding the loop, and this reaction manifests itself as a conduction current when the loop consists of a conducting material. Now an electro-motive reaction in the dielectric is impossible without a previous electric flux, hence every variation of the magnetic flux is accompanied by an electric flux, just as every variation of the electric flux is accompanied by a magnetic flux. The law connecting the variation of the flux of one type to the integral flux of the other type is formally the same in each case.

The question, How does the reaction of the magnetic field against a change of the cur-

rent in any part of it manifest itself? is now easily answered. Evidently since this change of the current is accompanied by a proportional change of the magnetic flux in every part of the field the reaction will be an electro-motive reaction against the electro-motive force tending to produce this change in the current. It is evident also that the electro-motive reaction is proportional to the rate of change of the current; that is to say, the current seems to behave like a moving body in consequence of its inertia. For a moving body opposes an inertia reaction against every force tending to change its velocity, and this inertia reaction is, according to Newton's second axiom, equal to the rate of change of momentum. Hence the striking formal resemblance between the laws of electro-magnetic and magneto-electric induction and the laws of inertia reactions of a connected material system. This is the second essential feature of the modern electro-magnetic theory which Maxwell emphasized by his mechanical models, illustrating the actions going on in the electro-magnetic field.

Summing up the foregoing brief account of the Faraday-Maxwell theory, we can say that, broadly speaking, this theory rests on two laws: *a.* The law of flux. *b.* The law of the variation of the flux. These two laws are formally the same as they were in the old theory, but their meaning is radically different. This difference has been brought about by a substitution of a new view of the electric and of the magnetic force in place of the doctrine of direct action at a distance, the view, namely, that electric and magnetic forces at any point of space are reactions due to the physical state of the dielectric in that point. This state is completely determined by the fluxes in that point and the rates of variation of the fluxes in every point of the field.

The account of the ordinary electro-magnetic phenomena in which the electro-mag-

netic forces are either constant or slowly varying is practically the same in the two theories. The radical difference becomes apparent when these variations are rapid, for it is then only that the currents in the dielectric both the electric and the magnetic show their real power. Hertz was the first to show us how to produce these rapid changes by the disruptive discharge of a Leyden jar.

Maxwell's Electro-magnetic Theory of Light can now be easily stated. Formally it is the same as the Dynamic Theory. For this one starts from the hypothesis that light is a vibratory motion of a substance which is a particular form of matter of very small density and very high rigidity. The fundamental laws of the Dynamic Theory of Light are, therefore, Newton's axioms, particularly the second law of motion, and the law of elastic displacement. Now these two laws bear a perfect formal resemblance to the law of variation of flux and the law of flux respectively; it follows, therefore, that since these two theories start from the same formal laws they will, formally, account equally well for all the simpler phenomena of light.

It would lead us much beyond the already extensive limits of this discussion to dwell even briefly upon the superiority of the electro-magnetic theory over the other theories. I shall mention a few only of the most striking features of this comparison. First, it makes no hypothesis as to the material constitution of ether; the Dynamic Theory does this and fails to reconcile some of its hypotheses, as, for instance, the very high rigidity, with well-known physical facts. The only hypothesis which the electro-magnetic theory makes is that its two fundamental laws apply to ether as well as to any other dielectric. In fact, it defines the fundamental physical properties of ether by these two laws just as Mechanics defines the fundamental phys-

ical properties of matter by Newton's axioms and the law of elastic deformation. It is in this sense that Maxwell's electro-magnetic theory may be called the Dynamics of Ether and treated distinctly from Dynamics of ponderable matter. Second, the hypotheses of the electro-magnetic theory admit of a direct experimental test, those of the Dynamic Theory do not. The Hertzian experiments furnished this test for the electro-magnetic theory and verified its hypotheses. Third, the beautiful picture of the phenomena of dispersion and absorption of light which Helmholtz gives us in his extension of Maxwell's theory forms by reason of its elegant simplicity a striking contrast to the mechanical model of these phenomena which he gave us some twenty years ago. Consider as Helmholtz does the electro-magnetic forces that must be acting between the luminous wave and the definite electric charges which Faraday detected long ago in every valency of the atoms of ponderable matter, and the cloud of uncertainty and of ignorance which for a long time seemed to hang over the region of these most interesting phenomena of light clears away and leaves us rejoicing in the possession of new knowledge, more beautiful than anything that we have ever known before.

"One cannot study this wonderful theory," says Hertz, "referring to Maxwell's Electro-magnetic Theory of Light," with out feeling from time to time that there resides in its mathematical formulæ an independent life and an individual intelligence; that they are wiser than we are, wiser than their discoverer; that they give us more than was formerly put into them."

Boltzmann expresses the same sentiment as Hertz by placing the following verse from Goethe's *Faust* as the motto of the second volume of his lectures on Maxwell's electro-magnetic theory:

War es ein Gott der diese Zeichen schrieb,
 Die mit geheimnissvoll verborg'nem Trieb
 Die Kräfte der Natur um mich enthüllen
 Und mir das Herz mit stiller Freude füllen.

The summary with which Hertz concluded his famous lecture 'On the Relation between Electricity and Light,' cited above, is the most comprehensive statement of the tendencies of modern electrical research that I know of. I shall, therefore, conclude my discussion with a translation of this summary, hoping that I have succeeded in paving the way to a clear understanding of the following comprehensive language of one of the most profound students of Faraday and Maxwell. Hertz speaks as follows:

"No longer do we see the flow of currents nor the heaping up of electricities in conductors. We only see the waves in air, passing through each other, dissolving and uniting, intensifying and neutralizing each other. Parting from the region of purely electric we arrive step by step to purely optic phenomena. We have crossed the pass; our path grows less steep and approaches a level. The union between light and electricity which the theory surmised, expected, predicted, has been accomplished, comprehensible by the senses, intelligible to our common intelligence. A broad view into both regions greets us at the highest point which we have reached, at the pass itself. The domain of optics is no longer limited to ether waves, the length of which is only a small fraction of a millimeter; it extends to waves which are measured by decimeters, meters, kilometers. But in spite of this extension, this domain appears to us, when viewed from here, as an appendix only to the domain of electricity. This last one gains the most. We see electricity in a thousand places where formerly we found no sure record of its presence. In every flame, in every luminous atom, we see an electric process. But even a non-luminous body, as long as it radiates heat,

is the seat of electric impulses. Thus the domain of electricity is being extended over all nature. It approaches us personally; we learn that in reality we possess an electric organ, the eye. This is the view of the things below, the view of details. The view from this standpoint of the things above, the view of the lofty peaks, the general aims, is not less inviting. There lies directly before us the question concerning direct actions at a distance. Do they exist? Among the many which we believed to possess, one only remains, gravitation. Does this one also deceive us? The law, in accordance with which it acts, makes it suspicious. In another direction, not far away, is the question concerning the nature of electricity. It hides itself, when viewed from here, behind a more specific question concerning the nature of electric and magnetic forces in space, and directly alongside of this, rises the mighty chief problem concerning the nature, the properties of the medium which fills all space, the ether, its structure, its rest or motion, its infinite extension or its finite boundary. Stronger and stronger grows the appearance that this question towers way above all the others, that a knowledge of ether will reveal to us not only the nature of former imponderables, but also of old matter itself and its innermost properties, gravity and inertia. The quintessence of primeval physical doctrines is preserved in the words that 'all that is is made of water, of fire.' Physics of to-day approaches the question whether all that is is made of ether? These things are the ultimate aims of our Science, of Physics. They are, to continue our simile, the last ice-capped peaks of its highlands. Will it ever be granted to us to place our foot upon one of these peaks? Will that happen late? Can it be soon? We do not know it. But we have gained for further efforts a foothold which is a step higher than those which were used before; the

path is not cut off by a steep mountain side; the ascent, at any rate the nearest visible part of it, presents a moderate incline only, and among the rocks there are narrow paths which lead on high; there are many zealous and skilled investigators; how can we but look hopefully ahead to the successes of future efforts?"

M. I. PUPIN.

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THE BERNE PHYSIOLOGICAL CONGRESS
(II).*

THURSDAY, September 12. Morning demonstrations and papers (Chairmen, Profs. Dastre and Einthoven).

Prof. S. Arloing (Lyons) described experiments showing that the persistence of electric excitability of the peripheral ends of divided nerves was of long duration, although varying with the animal and nerve experimented on. The excitability of the spinal accessory and facial nerves lasted in dogs four to five days, in asses eight to ten days. In one case the peripheral end of a cat's sciatic was excitable after thirty-one days. The different kinds of nerve fibres in one nerve trunk have different rates of degeneration and their existence can be thus demonstrated; for instance, the vagus of some animals seven or eight days after section has lost its inhibitory action on the heart, and now produces acceleration on stimulation. In the case of an ass, stimulation of the peripheral end of the vagus produced standstill of the heart accompanied by a rise in blood pressure, which Prof. Arloing considered to be due to tetanus of the cardiac muscle. The graphic record of this experiment was shown.

Discussion by Prof. Schiff.

Dr. M. Arthus (Paris) discussed the action of lime salts in promoting the coagu-

lation of the blood. He did not agree with the late Prof. Al. Schmidt that the action of the oxalates in preventing clotting was a specific one, independent of the precipitation of lime salts, as the same action was possessed by citrates and fluorides.

Discussion by Prof. Kühne.

Prof. J. v. Kries (Freiburg) discussed the color-blindness, except for red, of eyes which have been long unexposed to light. He did not agree with Hering that this was due to the activity of the white-black substance alone, for he found the periphery of the retina one to two hundred times superior to the center, and held that the retinal rods by virtue of their visual purple possess the power of adaptation to darkness, while the cones distinguish colors.

Discussions by Profs. Grützner, Hensen, Pflüger (Berne) and Kühne.

Prof. A. Gamgee (Lausanne) described his investigation of the absorption bands in the outer violet and ultra-violet produced by haemoglobin and its derivatives, photographs of which were shown. The absorption bands of Turacin, the pigment containing copper obtained from the feathers of certain birds, were also described. Its ultra-violet absorption band is identical with that of reduced haemoglobin.

Discussion by Prof. Tschirch.

Prof. S. Epstein (Berne) gave an experimental demonstration of the increase in visual acuity caused by auditory impressions. He did not agree with the localization of the nervous process in the cerebral cortex, but held it to take place in the corpora quadrigemina, in which the auditory stimuli are reflected on to the optic nerves, these functioning as efferent as well as afferent nerves. In favor of this view he described an experiment in which faradisation of the cochlear nerve produced movements of the eyes and increased sensibility of the conjunctiva. Prof. Epstein also showed an improved perimeter to be used

*Continued from Vol. II., No. 50, p. 781. (December 13, 1895.)

in the dark, which rendered simulation extremely difficult.

Prof. Burdon Sanderson (Oxford) showed projections of photographic records of the movements of the capillary electrometer caused by muscle currents. These justified the proposition that there are two kinds of electrical response of a muscle to indirect stimulation, that accompanying the wave of excitation and in addition to this a diminution of the E. M. F. of the previously existing muscle current. This latter is evoked by the constant current, by stimuli of great frequency, by chemical stimulation, and in the strychnine spasm.

Dr. A. Waller (London) projected photographs of the excursions of a Thomson's galvanometer produced by the action current of nerve stimulated for one eighth of a minute every minute and subjected to the action of equimolecular solutions of Na Cl, Na Br, and Na I, of ether and chloroform, and of various alkaloids.

Discussion by Dr. Boruttau and Prof. Fano.

Dr. P. DuBois (Berne) showed an electro-dynamometer for physiological and therapeutical purposes.

Dr. A. Beck (Lemberg) and Prof. Cybulski (Cracow) demonstrated the electrical effects accompanying cerebral activity in the monkey.

Prof. N. Wedensky (StPetersburg) demonstrated the effects of simultaneous stimulation in different rhythms of two points of a nerve, the action currents of which were led through a telephone. Variations of the tone heard were produced by interference between the two stimulations.

Afternoon demonstrations and papers (Chairmen, Profs. Vitzou and Fredericq).

Dr. F. Laulanié (Toulouse) described his respiration experiments in a closed chamber, and discussed the results obtained.

Discussions by Prof. Zuntz.

Prof. W. Rutherford (Edinburgh) projected micro-photographs of preparations of crayfish muscle, the structure of which he has investigated in the contracted and in the relaxed condition. He believes in the fibrillary structure of muscle. Three stages of the process of contraction can be made out, the first two of which are due to the absorption of water by Bowman's elements, which in the third stage actually shorten.

Prof. de Burgh Birch (Leeds) described with the aid of lantern projections the graphic methods used in his laboratory by students, which combine convenience with economy.

Prof. I. Rosenthal (Erlangen) showed his method for the estimation of carbonic acid in air for hygienic purposes. The final titration is done with the aid of phenolphthalein.

Discussion by Profs. Zuntz and Grützner.

Dr. M. Cremer (Munich) described his experiments on the formation of starch in potato sprouts from various sugars. Experiments made hitherto have shown a parallelism between the fermentibility and power to form glycogen of the simple sugars. Dr. Cremer found that the fermentible sugars, Dextrose, Lævulose and *d.* Lactose form starch in potato sprouts kept in the dark and free from or with but little starch. A positive result was also obtained once with *d.* Mannose. On the other hand, the unfermentible sugars, Rhamnose, Arabinose, Sorbose and Glucoheptose, gave negative results, but Xylose a positive one. Microscopical preparations were shown.

Dr. E. Gley (Paris) demonstrated experimentally that the intravenous injection of 'peptone' into a dog, the great lymphatic vessels of the liver of which had been tied, does not hinder the coagulation of the blood as usual. He concluded that under the influence of peptone the liver gives rise to some substance preventing coagulation.

Discussion by Dr. Arthus and Profs. Fano and Kühne.

Dr. A. Jaquet (Basle) discussed the influence of tepid baths on nutrition. In fever the number of red corpuscles in the blood is often considerably diminished. After a bath of about the temperature 22° R, the red corpuscles usually increase in number to the extent of from 100 up to 900,000 per cubic millimeter. A similar but slighter effect is seen in individuals not suffering from fever. Antipyrin does not act upon the blood. The artificial heating of a rabbit to 40° and above decreases the number of red corpuscles in the veins of the ears, but increases their number in the liver. Cooling baths would appear, therefore, to improve the tone of the circulation, and thereby better nutrition. The antipyretic action of baths is of secondary importance.

Discussion by Prof. Richet.

Dr. De Rey-Pailhade (Toulouse) demonstrated the formation of sulphuretted hydrogen in liquids containing sulphur by a yeast infusion. He considers a substance to be present in the latter, which he calls 'Philothion,' and which can produce oxidations and syntheses by the formation and interaction of nascent hydrogen and oxygen.

Dr. J. V. Uexküll (Heidelberg) showed a small apparatus for the mechanical stimulation of nerve.

Dr. L. Asher (Berne) showed a rat holder, and myographic records taken with its help.

Dr. F. Schenck (Wurzburg) discussed the interpretation of the observation of Dogiel with the dog, rabbit and cat that stimulation of the cervical sympathetic causes, in addition to dilation of the pupil in the same side as the stimulated nerve, contraction of the pupil of the opposite side. Dr. Schenck's experiments with the dog had shown that, if light was prevented from entering the eye of the stimulated

side, the contraction of the pupil of the other eye did not occur, and must have been, therefore, in Dogiel's experiments a consensual reflex, due to the increased amount of the light admitted by the dilated pupil. This explanation could not apply to the rabbit, as in this animal the consensual pupillar reflex does not occur, but, correspondingly, Dr. Schenck could not here confirm Dogiel's original observation. He explained Dogiel's result that stimulation of the central end of one vagus produced contraction of the pupil of the same side and dilation of the pupil of the opposite side, by a previous section performed for other purposes of the cervical sympathetic of the side stimulated.

Friday, September 13. Morning demonstrations and papers (Chairmen Prof. Rosenthal and Mr. Langley).

Dr. J. B. Leathes (London) discussed the osmotic changes between the blood and tissues. He described the effects of strong solutions of cane sugar and dextrose and of hypo-, iso-, and hypertonic solutions of NaCl on the passage of fluid through the walls of the blood vessels. Dr. Leathes had found the osmotic pressure of the lymph in the thoracic duct to be 1-2 % higher than that of the blood.

Prof. N. Wedensky (St. Petersburg) showed the following experiments: Stimulation of the frog's sciatic nerve with very strong and rapidly repeated shocks soon produced relaxation of its muscle, which, however, became again tetanically contracted when the strength of stimulation was reduced. Reduction of the frequency produced the same result. There is, accordingly, for every strength of stimulation an optimum frequency, and *vice versa*. When the muscle during strong stimulation of its nerve has become relaxed, direct stimulation of it with moderately strong shocks produces contraction only when the stimulation of the nerve is interrupted.

This is to be interpreted as due to the motor nerve endings under pessimum stimulation acting inhibitorily on the muscle, fatigue being excluded.

Dr. F. Lüscher (Berne) described his experiments on the laryngeal nerves in connection with movements of the oesophagus. Stimulation of the recurrent laryngeal was first found to cause a complete act of swallowing. Three fine branches it gives off to the oesophagus were found by localized stimulation to innervate three overlapping segments of it, local contractions of these being produced. Stimulation of the central end of the divided recurrent, its fellow of the opposite side being intact, gives rise to a feeble act of swallowing.

Prof. H. P. Bowditch (Boston) demonstrated a simple model illustrating the mechanism of the ankle joint, Weber's doctrine regarding which was erroneous. The relations between the power and the weight, both when the former (represented by a spring balance) acts from a fixed point external to the system to be moved, and when (as is the case actually in the body) it acts from a point forming part of that system, can be readily shown.

Discussion by Prof. Grützner.

Prof. Hensen (Kiel) demonstrated that a stream of air set in vibration by passing a reed cannot sound an organ pipe or resonator like a steady stream. If the stream is strong the resonator or organ pipe alone sounds; if it be weak the reed alone.

Discussion by Prof. Grützner.

Dr. A. White (London) demonstrated his method for artificial circulation through the frog's heart.

Afternoon demonstrations and papers (Chairmen, Profs. Fredericq and Herzen).

Dr. O. Lanz (Berne) showed various animals, some of which had had their thyroid glands removed ('athyreotic'), while the others were having thyroid glands administered to them ('hyperthyreotic'). Thy-

roidectomy diminished the egg-laying power of hens, while thyroid feeding increased it. If rodents (which have hitherto been held to be immune to the effects of thyroidectomy) are operated on when young, cachexia sets in. Hyperthyreotic animals bear apparently normal young, but these soon show disturbances of growth and function; a kitten taken from its mother and fed on cow's milk, however, henceforward developed normally. A thyroidectomised dog had been kept alive six months by feeding with glands and injections of their extract, cessation of which brought on the characteristic cachexial symptoms. Tolerance of the loss of the gland is not established.

Discussion by Dr. Hanau, Profs. Grützner and Herzen.

Prof. E. Drechsel (Berne) gave an account of his investigations into the chemistry of the hornlike skeletal substance of *Gorgonia Cavolinii*, a soft coral. This is insoluble in ordinary solvents, but soluble in strong hydrochloric acid. The dried material contains nearly 8% of iodine, and about 2% chlorine, while the whole ash is only about 7%, the iodine being therefore at any rate partly in combination with an organic substance. From the solution of the skeletal substance in baryta water, an organic iodine compound was isolated, provisionally called iodogorgonic acid, which is probably moniodoamidobutyric acid. This is the first organic iodine compound which has been obtained from an animal. It is derived in all probability from the destruction of a proteid substance containing iodine.

Prof. C. S. Sherrington (Liverpool) demonstrated an experiment previously described by him. After division of the 3d and 4th cranial nerves of a monkey the eye is deviated outwards by the uncompensated action of the rectus externus. Stimulation of the cerebral cortex at a point above the 4th frontal convolution

now produces a rotation of the eye inwards due, according to Prof. Sherrington, to an inhibition of the activity of the nucleus of the 6th nerve. Stimulation of the occipital lobe was without effect.

Dr. A. Waller (London) showed photographic records of the retinal currents produced by stimulations by light.

Discussion by Prof. Kühne.

Dr. Axenfeld (Perugia) showed an experiment on binocular color contrast. If, by means of a colored glass before one eye, one of the two crossed transparent double images of an opaque object is made to appear colored, the other image appears of the complementary color.

Dr. C. Phisalix (Paris) had found that the blood of the Salamander not only has the power to give immunity against the poison of this animal, but renders frogs and guinea pigs, into which it is injected, able, to withstand much larger doses of curare than they otherwise can.

Dr. Z. Treves (Turin) communicated experiments, the graphic records of which he showed, demonstrating that different impulses inhibitory of inspiration as well as expiration, pass along the vagi nerves. Their division, after the prevention of all active expiration by section of the cord, can produce more or less marked inspiratory tetanus, which is cut short by weak faradisation of the central ends.

Discussion by Dr. Boruttau and Prof. Herzen.

Prof. A. Mosso (Turin) gave the results of his experiments on the influence of rarefied air on man made on the summit of Monte Rosa (4,600 meters above sea-level). In absolute rest and especially during sleep the respiratory gaseous interchange is lessened, and even standstill of respiration may occur. This must be due to the lessening of the amount of carbonic acid in the blood, as must also be the accompanying quickening of rate of heartbeat. To this

condition of lessened carbonic acid in the blood Prof. Mosso gave the name of Akapnia. He described also experiments made on apes in rarefied oxygen, the pressure of which was, however, greater than the partial pressure of oxygen in air. In spite of this the apes showed symptoms analogous to those of mountain sickness. These are supposed to be due both to Akapnia and the direct influence of lessened atmospheric pressure on the nervous system.

Discussion by Prof. Zuntz.

Prof. N. Zuntz (Berlin) gave the results of experiments made by Dr. Schumburg and himself, as well as those made by Dr. Loewy on the functions of respiration and circulation in rarefied air. He laid stress on individual differences of effects observed, and pointed out that moderate regular movement may put an end to dangerous symptoms, while, as is well known, great muscular exertion favors the onset of mountain sickness.

At a business meeting on the morning of September 13 it was decided to hold the next meeting of the Congress at Cambridge, in the first week of September, 1898, with Prof. Michael Foster as President. Profs. Sherrington (Liverpool), E. Fredericq (Liège) and Grützner (Tübingen) were elected General Secretaries.

The admission of members to future congresses, the bibliography of physiological literature, the universal use of the metric system by physiologists were discussed, and other questions were relegated to a committee.

During the Congress week there was an interesting exhibition of physiological apparatus and preparations by Profs. Einthoven, Kahlbaum, Kronecker, Mosso, Tschirch and Dr. Cowl; and by the following mechanicians: Albrecht (Tübingen); Castagna (Vienna); Diederichs (Göttingen); Geissler (Bonn); Hennig (Erlangen); Petzold (Leipzig); Pfister (Berne); Runne

(Heidelberg); Schenk (Berne); Siedentopf (Wurzburg); Streit (Berne); Westien (Rosstock); Zimmerman (Leipzig).

CURRENT NOTES ON PHYSIOGRAPHY (XXI).

THE MOORS OF NORTHWEST GERMANY.

At the eleventh session of the German Geographical Congress, held at Bremen in Easter week, last spring, Dr. Tacke gave an account of the moors of northwest Germany, their utilization and their economic importance. He described two classes: the low marshy moors, of grassy growth, and the upland moors, of peaty and heathery growth; the first rich and the second poor in calcareous and nitrogenous matter. When sufficiently drained, spread over with sand, and enriched with artificial potash- and phosphate-bearing fertilizers, the low-lying marshy moors well repay cultivation. In the last thirty years extensive areas of waste land have thus been brought into productiveness. The more extensive upland moors are less easily redeemed. An old but ill-advised method consists in burning off the peaty surface at the end of a dry season, producing wide-spread smoky skies. An improved method, introduced from Holland, requires the stripping of the peat, which may be sold for fuel, and the mixture of the bottom soil with the underlying sand. Then after sufficient fertilizing, the surface becomes fruitful. Extensive undertakings for colonizing the moors have been successfully carried out in recent years. (*Geogr Blätter*, Bremen, xviii, 1895, 198-202.)

THE ISLANDS OF EAST FRIESLAND.

THE islands of East Friesland, lying along the low German coast between the estuaries of the Ems and the Weser, are described by Buchenau (*Geogr. Blätter*, Bremen, xviii, 1895, 202-204) as the last fragments of a formerly continuous coastal margin, built of sand drifted by waves and

winds. Dunes cover much of the surface. Behind the coastal barrier, at first grassy moors, then fresh-water reed-marshes and finally salt-water fens were formed on the slowly sinking mainland, the rate of depression being estimated as certainly less than the figure usually quoted, or three-fourths of a foot per hundred years; but in the eleventh century a more rapid sinking probably took place, as great losses of land followed that date. When first formed, the fens behind the sandy coastal barrier must have had but a small run of tide; it is presumed that the English Channel had not then been worn through, and that, the tides entered the North Sea only around Scotland. After the southern Channel was at last opened—about 1000 B. C., as estimated by some geologists—the tides gained greatly in strength; the coastal barrier was overflowed and repeatedly broken through; the fenland, flooded at high tide, bare at low, was gradually washed away. From the time when the Channel was opened, the people waged an unceasing battle with the sea, and as continually suffered defeat; until at last, driven by necessity, they planned a systematic defense against storm and wave, thus rescuing about half of what had before been lost. The vegetation of the islands is well adjusted to its exposed situation. The grass on the open meadows is kept very short by the action of the winds. Bushes are found only in the valleys between the dunes. There are no trees, except when planted near sheltering houses or dunes; any branch which rises above its shelter is soon killed by the storm winds.

PHYSIOGRAPHIC NOTES FROM ICELAND.

JOHNSTON LAVIS, well known from his studies on Vesuvius, went to Iceland in 1890, and contributes an entertaining account of his expedition to the *Scottish Geographical Journal* for September of this year. Interesting topographic features are

the *gjas*, or rifts in the great lava beds, one to three meters wide and of unknown depth, fairly straight over large areas and explained by the traveller as the result of laccolitic accumulations beneath, by which the surface flows are somewhat raised, arched and cracked. The more fertile districts are covered with alluvial detritus brought down by streams from the various Jökulls; but in some cases the wash of gravel and boulders carried by floods from snow melted rapidly by volcanic heat has been so tumultuous as to devastate the surface over which it is spread. The rivers here subdivide into numerous distributaries, across which the traveller has to wade repeatedly. One of the greatest of these stony deserts is the Myrdals-sandr, caused by the eruption of the Kötlugja; the tremendous force of the inundation is shown by the large boulders which have been transported dozens of kilometers from the foot of the highlands down a slope of, for the most part, very small inclination. The Skapter eruption of 1783, "the greatest outflow of lava known to have occurred in historic times," filled the valley of the Eldvatn and thereby displaced a river which now flows on the lava surface; but so nearly level is this surface that the river is subdivided into many channels—sixteen, where the author traversed it—no one channel having yet grown to be the master of the whole. Thingvall Lake appears to have had a curious origin; a prehistoric lava flood filled a valley, rising to a considerable depth above some barrier, and freezing a surface layer 32 metres thick; then a vent was opened by which the still molten under lava was drained away, and the surface layer settled down in a basin-like depression, some 8 km. wide by 35 km. long, in the bottom of which the lake now stands among the disjointed fragments of the lava crust. Wind action is very noticeable; much of the older rock surface about Cape

Reykjanes is rounded and polished by the sand blast; sand dunes are numerous on this peninsula, where 'the most dreadful dust storms' occur. Much of the pasture soil is wind-blown, collected at first among lichens and gradually coming to support a growth of turf; where the grass happens to be worn away, the wind blows away the soil; thus a farm may be made or marred in a few years. The careful farmer keeps his turf in good repair.

SABLE ISLAND.

THIS lonesome and dangerous island off the coast of Nova Scotia is recently described by G. Patterson (Trans. Roy. Soc. Canada, xii, 1894, 2°, 3-48). A bank that measures about 200 by 90 miles culminates in the island, now twenty miles long and one mile wide. It consists of two parallel ridges of loose gray sand, stretching east and west, and somewhat convex to the south. Between the ridges lies a long narrow 'lake' that is sometimes connected with the sea by inlets on the south, but these are often closed by storms, and then there are no harbors even for small vessels, and landing is generally difficult. Shoals extend far beyond the ends of the island, east and west, producing a terrible line of breakers with a total length of fifty miles. Strong, conflicting and irregular currents run about the island; floating wreckage sometimes makes a circuit around it. Fogs and storms are frequent; 190 wrecks have been recorded since 1801. The island is rapidly wasting under the attack of the waves, having been 40 miles long by two and a-half wide in 1700. About 1814 the rate of wear was nearly a mile a year. In 1881-82 much ground was lost at the western point during violent storms. In one severe gale, a strip seventy feet wide and a quarter mile long was removed; in another, a strip of the same length and forty-eight feet wide; at one time thirty feet of the land margin

sank down in a few hours. A lighthouse built in 1873 at a cost of \$40,000 was undermined and fell in 1882; it was rebuilt a mile inland, but in 1888 was removed two miles further east. The winds cause a continual change in the form of the sand dunes. Landmarks are thus blown away; hollows and ponds replace hills, and breaches in the sod near the few houses are carefully repaired to prevent the thin soil from being blown away. Wild horses of a small and hardy breed roam over the island in separate herds, each led by an old male. They numbered about 300 in 1828; 400 in 1864; 150 to 250 now. Their numbers have sometimes decreased by starvation caused by the burial of pasturage under the drifting sand; and they have not infrequently been eaten by the inhabitants. The unbalanced condition of the smaller imported fauna is curiously illustrated. English rabbits were introduced at one time and soon overran the island; but they were exterminated by rats that came ashore from some vessel. The government then sent cats to the island, and these, after extinguishing the rats, became so numerous that dogs and shot guns were brought to destroy them. Rabbits were then imported once more, and again became numerous; but were exterminated a second time by snowy owls.

The absence of ledges and boulders suggests that this strip of loose sand is only the vanishing remnant of a long bar, formed by wash from some larger island of glacial drift, now destroyed.

THE PHYSICAL FEATURES OF MAURITIUS.

'The physical features and geology of Mauritius' are described by H. deH. Haig (*Quart. Journ. Geol. Soc., London*, li, 1895, 463-471). In crossing the lava slopes of the island, one comes without warning on immense ravines, worn to depths of over a thousand feet by the rapid streams, fed by

the moist trade winds. There are few lakes; two occur in old craters, besides various shore lagoons and many marshes and pools among the newer lava beds. Long caves leading underground streams are very common in the fresh lavas. One extensive tubular cavern in solid lava, like a great railway tunnel, measured thirty feet in width and height, and was followed for a mile and a half without reaching its end; bubbly lava drops remain on its roof and walls. The writer accepts the current explanation that these caves are caused by the continued flow of the still molten central part of a lava stream after the surface has hardened and after the supply from above has ceased. Where cavern roofs have partly fallen in, the remnants form natural bridges, of which there are many examples. The most remarkable old cavern now appears as a strange dry ravine, a mile and a half in length, with vertical walls eighty feet high; the roof, having for the most part fallen in bodily, now lies on the floor of the ravine, where the ripple-marked lava surface may still be seen; but every few hundred yards parts of the roof still remain as bridges. In one case a cavern roof was burst upward by the rise of its torrent, fed by the heavy rainfall of the hurricane of February, 1876.

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CURRENT NOTES ON ANTHROPOLOGY (XVII.).

THE CRADLE OF MAYAN CULTURE.

THE results of Mr. Mercer's explorations of the caves of Yucatan (see *SCIENCE*, p. 766) corroborate in a noteworthy manner the studies of the Mayan MSS. and art relics. The cave-hunters discovered no trace of a culture lower than that of the historic Mayas. These, therefore, came into the peninsula already semi-civilized. The acute analyst of Mayan art, Dr. P. Schellhas reached some years ago the same

conclusion, and repeats it with added evidence in the *Internationales Archiv für Ethnographie* (Bd. VIII., Heft. III., 1895). The cradle of Mayan culture, he maintains, was south of the peninsula of Yucatan and in the interior. The subject which leads up to his statement is offered by the decorations on some ancient earthenware vases from Guatemala, which are described and portrayed.

Basing an article on a similar series of pottery from the same district, Dr. E. Seler, in the *Verhandlungen* of the Museum of Ethnography of Berlin, points out that throughout western Guatemala, Quirgua probably included, the fictile art and the decorative designs have such close analogies that all this territory must have been under the immediate influence of the cultured nation whose highest products we see in the remains at Copan. The question now presents itself, was it about Copan, in the extreme east of the Mayan territory, or about Palenque and Ocoingo, in its western extremity, that this culture had its origin?

ANCIENT MEXICAN HIGHWAYS.

In a lecture delivered last August before the German Anthropological Society (reported in the *Correspondenz-blatt*, September), Baron von Brackel described several highways constructed by the ancient inhabitants in western Michoacan. They are six or seven feet wide, laid with unhewn large stones, the surface slightly shelving so as to shed the water freely, protected by stone facing, both above and below, where there is danger of the banks giving way. Their direction is almost rectilinear, and evidently the deep ravines and water courses were crossed by hanging bridges, as the road continues either side of them. The paving was so thoroughly done that many miles of it are in perfect condition.

Although in many parts the stones have been taken away for modern constructions,

the speaker believed that it would not be difficult to trace out and map the whole system of these highways. As far as he had accomplished this, they appear to center toward some distant point, which he thinks may be the Bay of Maruata, on the Pacific coast. The vicinity of Coalcoman, where these highways are especially noticeable, is rich in copper and other minerals, and the idea suggests itself that these paved paths were built to facilitate the transportation of such materials to the seashore.

D. G. BRINTON.

SCIENTIFIC NOTES AND NEWS.

HARVARD COLLEGE OBSERVATORY.

PROF. E. C. PICKERING announces in circular No. 3, the discovery of a new variable star of the Algol type. The star B. D. + 17° 4367, magn. 9.1, whose approximate position for 1900 is in R. A. 20^h 33^m.1, December + 17° 56', appears to be a variable star of the Algol type. On July 18, 1895, Miss Lousia D. Wells found that no trace of this star appeared on the photograph I 4359, taken with the 8 inch Draper telescope on September 26, 1891, exposure 16 m. On 71 other plates taken from June 30, 1890, to October 5, 1895, the star appears of its normal brightness. On December 12, 1895, at 10^h 42^m Greenwich Mean Time, Prof. Arthur Searle, who had watched this star on several nights, found it more than a magnitude fainter than usual. During the next half hour it diminished about half a magnitude more. Meanwhile, a photograph taken with the 8 inch Draper telescope, I 14036, confirmed the diminution in light. Unfortunately, at 11^h 15^m G. M. T., clouds covered the region, and the star, although carefully looked for, was not seen again that evening. The change in brightness appears to be rapid and the range of variation to be large, exceeding two magnitudes. The nearest bright star is B. D. + 17° 4370, magn. 7.0, which follows 14^s and is south 1'. The variability of B. D. + 17° 4370 has been suspected by Espin (*English Mechanic*, Vol. LXII., 334) and also independently by Mrs. Fleming in 1890.

SWEDISH MARINE ZOÖLOGICAL STATION.

THE December number of *Natural Science* contains an interesting account, by Mr. F. A. Bather, of a visit to the Marine Zoölogical Station at Kristineberg, on the Island of Skaftö, Sweden, on the south side of the Gullmar-fjord. The fjord cuts deep into the land, and has a varying bottom of clay, gravel, rock, *Zostera*, algæ, shells and mud; immediately outside Kristineberg it reaches a depth of thirty fathoms, and six miles further up a little over eighty fathoms. A number of rocky islands shelter the mouth of the fjord against the sea. Animal and vegetable life are richly represented and provide a boundless field for research.

The station was established in 1877 through the efforts of Sven Lovén. The initial endowment was the sum of \$15,000 bequeathed by Anders Fredrik Regnell to the Royal Academy of Science in order to found a Zoölogical Station that should belong to the Academy. The Swedish government placed \$2,775 and a gunboat completely equipped at the disposal of Sven Lovén during the summers 1877-9 to facilitate the study of the animal life of the Swedish seas, and this aided greatly in the first development of the station.

The laboratory provides working rooms for ten persons exclusive of the common room. It is furnished with aquaria and all necessary apparatus and supplies. The station is only open during the three summer months, as lack of funds (the yearly appropriation granted by the government is but \$550) does not permit it to be open at other times. For the same reason foreign students are not admitted. The students at the station are provided with work tables and all necessary appliances without charge, with no further expenses than those for board and lodging, which would amount to about \$18 a month.

Mr. Bather suggests that the station might with advantage be opened to foreign students who would gladly pay for the privilege of studying at Kristineberg. Under the present arrangement the student loses the great advantage of free intercourse with his colleagues from other countries.

'TIMBER.'

BULLETIN No. 10, of the Division of Forestry, of the U. S. Department of Agriculture, contains a discussion of the characteristics and properties of wood by Mr. Filibert Roth. The monograph enters into details concerning the weight, moisture, shrinkage, mechanical and chemical properties of wood, its durability and decay. It points out how different kinds of wood may be distinguished, and concludes with a list of the more important woods of the United States. In the introduction Mr. B. E. Fernow, Chief of the Division of Forestry, emphasises the fact that, although wood has been in use so long and so universally, there still exists a remarkable lack of knowledge regarding its nature in detail, not only among laymen, but among those who might be expected to know its properties; as a consequence, the practice is often faulty and wasteful in the manner of its use, and Mr. Fernow indicates ways in which it may be used to advantage.

Mr. Fernow says that "wood is now, has ever been, and will continue to be, the most widely useful material of construction. It has been at the base of all material civilization. In spite of all the substitutes for it in the shape of metal, stone and other materials, the consumption of wood in civilized countries has never decreased; nay, applications in new directions have increased its use beyond the saving affected by the substitutes. Thus, in England, the *per capita* consumption has increased in the last fifty years more than double, a fact which is especially notable, as the bulk of the timber used there must be imported, while iron and coal are plentiful in Great Britain. In the United States we can only estimate from the partial data furnished by census returns. By these we find the *per capita* consumption to have increased for every decade since 1860 at the rate of from 20 to 25 per cent. There is no country in which wood is more lavishly used than in the United States, and none in which nature has more bountifully provided for all reasonable requirements. In the absence of proper efforts to secure reproduction, the most valuable kinds are rapidly being decimated, and the necessity of a more rational and careful use of what remains is clearly apparent. By

greater care in selection, however, not only can the duration of the supply be extended, but more satisfactory results will accrue from its use."

GENERAL.

THE Results of the motorcycle contest promoted by the *Times-Herald* of Chicago are more hopeful in promise than in performance. When the prizes were offered on July 11 there were only known to be three self-driven road vehicles in the United States, but there were about seventy-five entries for the contest on November 2. As the time drew near, however, it became evident that only a small part of the vehicles would be ready. The contest was consequently postponed until November 28, but a purse of \$500 was offered for a preliminary race on November 2. The only two wagons to start were the Durea and the Benz-Müller, both gasoline motors, and only the latter completed the course of 92 miles, which it accomplished in 9 h., 30 min. On November 28, after snow and on roads as bad as possible, six contestants started, four with gasoline motors and two with storage batteries, but only the two wagons mentioned above completed the course.

WE learn from the *American Naturalist* that the Australian Museum at Sydney still suffers from small appropriations by Parliament, and during the year 1894 it was working with a reduced staff and with practically no money for increase or publication. Dr. Ramsay, owing to ill health, has resigned his position as curator after 20 years' service, but still retains a connection with the Museum. Mr. Robert Etheridge, Jr., has been appointed as his successor. The total income for the year 1895 was about £6,000. 120,000 persons visited the museum during the year, 34,000 coming on Sundays. Among the most interesting additions to the museum were a number of relics of Capt. Cook, the list of which would seem to indicate that this antipodal museum has about as large a collection of specimens collected by Capt. Cook and of memorials of him as has the museum at Oxford. The museum has also received a considerable collection of aboriginal pottery from Arkansas.

TWENTY-SIX fellows and foreign members of the Royal Society died during the year preced-

ing the recent anniversary meeting. It is perhaps worthy of note that the average age of these distinguished men of science at the time of their death was 76.8 years, which is far beyond the average. This is in part due to the fact that members are not elected to the Royal Society at an early age, but it indicates that scientific pursuits are conducive to a long life. Three members lived respectively to 95, 97 and 98, and eleven were over eighty years of age.

MR. M. S. BEBB, known for his researches and publications upon American Willows, died at San Bernadino, California, on December 5, at the age of 62 years. Mr. Bebb had published numerous and important papers on the genus *Salix*, and was preparing a monograph on the subject at the time of his death.

WE have received from Prof. Elisée Reclus a pamphlet describing his plan for the construction of a terrestrial globe on the scale of 1 : 100,000. This globe would have a circumference of about 400 metres, and elevations of 1 kilometer would be represented by 1 centimeter. It is proposed to cover the globe with a second globe for protection, this to be painted on the outside so that the large features may be seen at a distance. M. Reclus believes that such a globe would promote geographical discovery and topographical knowledge. It should be erected in the neighborhood of London, New York or Paris, and would cost about \$4,000,-000 (!), apart from the details of the relief.

WORK is now being commenced for the first time on the coal fields of Newfoundland. Cook announced to the Royal Society as long ago as 1766 that he had discovered coal on the island, and several workable seams of coal have been discovered and explored by Mr. J. P. Howley, director of the Geological Survey of Newfoundland. Newfoundland has important copper mines (it is eighth among the copper producing countries of the world), iron mines, etc., and the discovery of coal adds greatly to the productiveness of the mines and manufactures of the island.

THE Field Columbian Museum of Chicago has issued the first number of a series of Botanical Monographs (56 800 pp. and an index), which is entitled 'Contribution to the Flora of

Yucutan,' by Charles Frederick Millspaugh. The collection which forms the basis of this monograph was made last January, during an expedition to the ruined city of Chichen Itza, and the Islands of Mugeris and Cozumel, and is, according to the author, incomplete and fragmentary, on account of the excessive dryness of the season and the rapidity of movement of the party. The expedition was generously planned and carried forward by Mr. Allison V. Armour, of Chicago, and as it was conducted in his steam yacht it gave an opportunity of visiting the islands that would otherwise have been unattainable. In order that the work should be made as complete as possible, a careful compilation was made of all the publications concerning previous collections.

A SIMILAR report, by Mr. John M. Holzinger, has been issued by the U. S. National Herbarium of the Department of Agriculture, on a collection of plants made by J. H. Sandberg and assistants principally in northern Idaho, but to some extent in the adjacent parts of Washington and Montana, in the year 1892. The monograph contains 287 pages and includes a catalogue of species and a list of 1272 specimens obtained on the expedition. An index is appended.

ARRANGEMENTS have been made with the Metropolitan Telephone and Telegraph Company of New York by which the Weather Bureau will transmit information regarding weather forecasts to the general public. Any one may hereafter call for answers to special questions at any time and be sure of an immediate answer. Moreover, any subscriber who wishes to have all important weather news can send his name to the telephone company, and he will thereafter be telephoned by them whenever any marked change is expected.

At the Annual Meeting of the Royal Society of Edinburgh, which took place on November 25th, the following officers were elected: President, Lord Kelvin; Vice-Presidents, Prof. Copeland, Prof. James Geikie, the Hon. Lord Maclaren, the Rev. Prof. Flint, Prof. J. G. McKendrick and Prof. Chrystal; General Secretary, Prof. P. G. Tait; Secretaries to Ordinary Meetings, Prof. Crum Brown and Mr.

John Murray; Treasurer, Mr. Philip R. D. MacLagan; Curator of Library and Museum, Mr. Alexander Buchan.

WE learn from the American Geologist of the death, on October 27th, of Antonio del Castillo, director of the Mexican Geological Commission.

THE death is announced of Rev. A. E. Philimore Gray, of Wallasey, England, a well-known authority on antiquarian and archaeological subjects. He was elected a Fellow of the Society of Antiquarians in 1887.

THE annual meetings of the American Economical Association under the presidency of Prof. John B. Clark of Columbia College, and of the Political Science Association of the Central States, under the presidency of Prof. Albion W. Small of the University of Chicago, will be held at Indianapolis beginning on December 27th and continuing until January 2d. The first-named association will hold sessions on December 27th, 28th and 30th, and the latter on December 30th and January 1st and 2d. The program for December 31st is a joint one.

SENATOR SQUIRE introduced in the Senate on December 10th a bill providing for the increase of members of the engineer corps of the navy to 303, and providing for the teaching of naval engineering in properly qualified technological schools.

At the eleventh annual dinner of the London Institution of Electrical Engineers, on December 13th, speeches were made by the president, Mr. R. E. Compton, the Duke of Cambridge, and others. Sir J. Crichton Browne said that electrical engineers had added enormously to those nervous diseases with which he and his colleagues had to deal. Their discoveries had increased the strain and stress of existence, and had contributed to those wear and tear diseases that were one of the features of modern civilization.

PROFESSOR W. A. HERDMAN delivered a lecture on 'The Culture of the Edible Oyster' before the Malacological Society of London on December 12th. The lecture dealt with the cultivation of the oyster and chiefly with its cultivation in France. Among the important

features of the French system is that of devoting certain places to one stage of the work, and other places to other stages. From Archachon, for example, after being cultivated up to the age of about two years, the oysters are brought up for further advancement elsewhere and for fattening for the market. Prof. Herdman gave a warning in regard to the fat green oysters, the green in some cases being simply a disease, in which the true blue had got mixed up with the yellow. He remarked that the oyster cultivators, in drawing off the water periodically, trained the oyster to keep its mouth shut when out of the water, which is a point of some importance when it comes to be laid out in the market. The Italian method of culture differed from the French, inasmuch as the former is conducted on the vertical principles, by suspension of the oyster with ropes or twigs in deeper water, whilst the French method is the horizontal, in shallow beds from a few inches to a couple of feet deep. The oyster is said to live as long as twenty years, and those fittest for the market are of the age of about five years. Prof. Herdman stated that the American oyster is more prolific than the English oyster, producing as many as 60,000,000 ova at a time. The typhoid germ does not flourish in sea water at an ordinary temperature, but the question of typhoid fever, as propagated by oysters, is under Government investigation and is not yet settled.

UNIVERSITY AND EDUCATIONAL NEWS.

It is reported that \$300,000 of the \$1,000,000 given by Miss Culver, to the University of Chicago, will be used for the erection of a laboratory of biology on the grounds of the University. An inland biological station will probably be erected near the Yerkes Observatory on Lake Geneva, and the Marine Biological Laboratory at Woods Holl will be strengthened. About one-half of the entire sum is to be reserved for endowment. The buildings and endowments are, whenever it is suitable, to be named after Mr. Hull, from whom Miss Culver inherited the money.

MRS. MARTHA W. BROWN, of Manchester, N. Y., bequeaths to Dartmouth College a sum of

money to be left to accumulate until it reaches \$40,000, when it is to be used to endow the chair of Physiology to be called 'The William Brown Professorship of Human Physiology.'

DR. CHARLES PALACHE has been appointed assistant in mineralogy at Harvard University. Dr. Palache received the degree of B.S. from the University of California in 1891, was fellow in mineralogy there in 1892-93 and honorary fellow in 1893-94, received the degree of Ph. D. in 1894, and has spent the last year in advanced work at Göttingen.

WE have received from the Missouri Botanical Garden an announcement concerning garden pupils and garden scholarships. Three scholarships will be awarded by the director prior to the first of April next, and applications should be made not later than March 1st. The value of the scholarships is for the first year \$200, for the second \$250, and for the third and fourth years \$300, together with free lodgings.

THERE are said to be 2,610 medical students attending the several schools at Philadelphia; of these 900 are at the University of Pennsylvania and 725 at the Jefferson Medical College.

THE Herbarium of the University of Wisconsin is making special efforts to collect all plants that grow in the State. Mr. L. S. Cheney has been for several years in charge of the field of and herbarium work of the Botanical Survey of Wisconsin, and has already examined the plants of the Wisconsin River Valley from the headwaters to the Dells. Prof. Barnes believes that the function of State collections should be to represent the local fauna and flora, leaving the accumulation and maintenance of great collections to institutions which are established or endowed for this purpose, where proper provision can be made for their use.

LADY HERSCHEL has placed copies of observations made at the Cape of Good Hope by the late Sir J. F. W. Herschel, Bart., at the disposal of the trustees of the Mathematical Scholarships of the University of Oxford, with a request that one copy should be given annually to that candidate for the Senior Scholarship who distinguishes himself most in the part of the examination which relates to astronomy.

At a meeting of the electors to the Waynflete professorship of mineralogy, held at Magdalen College on December 13th, Mr. Henry A. Miers, M.A., Trinity College, was elected professor in the place of Prof. Story-Maskelyne, resigned. The emoluments of the professorship are £500 per annum, of which £400 is from Magdalen College and £100 from the University chest.

DISCUSSION AND CORRESPONDENCE.

AN EASY METHOD OF MAKING LINE DRAWINGS.

It is often difficult to get satisfactory cuts of apparatus or of natural objects to illustrate scientific articles. A half-tone, although the easiest to get, is somewhat expensive and liable to be poorly printed, and, on account of its vagueness of outline, is in many cases not as good for scientific purposes as a half diagrammatic line drawing. To get a cheap cut that can be printed on a newspaper press the original photograph must be redrawn in lines and dots. But not everyone has the time and skill to make an accurate line drawing, while if the photograph is sent off to a professional draftsman the expense is about the same as for a half-tone, and the drawing frequently fails to bring out the very point to be illustrated.

A line drawing with the accuracy of a photograph can, however, be easily made in this way: photograph the object, take from the negative a pale blueprint, on the blueprint trace the outlines with as much detail as desired using a crowquill pen and waterproof ink, put the print in water containing a few drops of ammonia, when the blueprint will fade away leaving the black lines on white ground, wash and dry, make such alternation or additions as are required, and the drawing is ready for reproduction by the zinc etching or other process. Of course if the photograph is several times larger than the cut is to be, the reproduction will be neater.

E. E. SLOSSON.

UNIVERSITY OF WYOMING.

[We are glad to give space to the above, although the method has already been recommended. For an apparently new and in many cases better method cf. Prof. Hallock's note on page 761 of the present volume of SCIENCE. J. McK. C.]

THE MEASUREMENT OF COLORS.

EDITOR OF SCIENCE—*Sir*: Mr. J. W. Lovibond, of Salisbury, mentions in *Nature* that his system of Tintometer glasses is in constant use in many laboratories and manufactories for enabling one to record and to reproduce exactly at a future time any given color; and that the method is so simple that it can be carried out by any intelligent workman. Does anyone know whether these glasses are in use in this country, or whether they can be obtained here?

C. L. F.

SCIENTIFIC LITERATURE.

ON THE STRUCTURE OF PROTOPLASM.*

WHAT is the structure of the most marvelous known substance, protoplasm, 'the physical basis of life,' is a question that has long waited its final answer. Probably the best solution thus far given is that found by Prof. Bütschli in the work imperfectly represented in what follows:

That the watery, jelly-like material we find in the most actively living parts of all plants and animals has any discoverable structure is by no means self-evident, and it is only by slow, uncertain steps that the conception of a visible physical structure in this soft living matter has become generally accepted.

The idea that protoplasm is a structureless, homogeneous fluid early met opposition from many who observed here and there facts that pointed to the existence of apparently solid portions in the protoplasm of various cells.

Remak in 1837 found the axis cylinder of vertebrate nerve fibers made up of very minute fibrils. Frommann in 1867 supposed a fibrillar structure was common to all protoplasm. Striated structures were seen in ciliated cells and in gland cells, while Pflüger in 1869 found fibrillations in liver cells.

The fibrils were then seen to be connected in the form of a reticulum. Thus Küpffer in 1870 describes the living protoplasm of the follicle

*Untersuchungen über mikroskopische Schaüme und das Protoplasma. Von O. Bütschli. Leipzig. 1892. 229 pp., 6 pl.

Investigations on Microscopic Foams and on Protoplasma. O. Bütschli. London. Adam and Charles Black. 1894.

cells of *Ascidia* as having a beautiful reticular structure. In 1873 Heitzmann described a reticulum in living *Amœbæ*, and in the same year Frommann saw networks in the living white corpuscles of the crayfish. In 1876 Schwalbe referred the fibrillar appearances of ganglion cells and of nerve fibers to the presence of a reticulum, and a year later Eimer brought the longitudinal striation of ciliated cells into the same group by observing the cross meshes connecting the fibrils.

In 1880, Schmitz supported the universal occurrence of reticular structures amongst plants while Frommann, four years later, found reticular structures in all the protoplasmic objects he examined. He regarded the network, however, not as constantly persisting, but as forming and disappearing. Leydig also found a reticulum everywhere; even the surface of cells was porous. He thought the reticulum was only a supporting part and that the true living substance was in the meshes of this framework. Van Beneden referred the reticular appearances to a trellis-work of fibrils in three dimensions of space. Carnoy made many contributions to the evidence for the existence of a network structure in protoplasm while Flemming and Schneider could perceive only the existence of fibrils.

While there was thus growing up a conception that protoplasm was not homogeneous, but that it contained fibrils which might be united to form a net, there were other views as to the structure of protoplasm. One of the strangest was that of Fayod, who, in 1890, from results obtained by injecting vegetable cells with mercury, concluded that protoplasm consists of long, hollow, spirally twisted fibers that are usually twisted to form the walls of hollow strings, which are also twisted. Previously Künstler maintained that spherules built up the cell as the cell did the tissue; each spherule had a dense wall and fluid contents, that is, was a vesicle. Much more general, however, was the recognition of granules within the protoplasm. Called microsomes by Hanstein in 1883, these minute specks were sometimes regarded as nodal points in a network, and again as being arranged in rows to make the apparent fibrils and reticulum. Bechamp in 1867 and Martin

in 1882 thought the granules might be living units, but Altmann becomes, from 1886-90, the chief exponent of the view that granules are the chief active, living constituents of protoplasm. In fact, he even supposes that protoplasm may have arisen as a sort of zoöglea mass made by granules that at one time led a separate existence, much as bacteria exist to-day!

Although it cannot be denied that in some places protoplasmic bodies appear quite homogeneous in spite of all attempts to analyze them optically yet it is generally conceded at the present day that protoplasm has a structure, that it has fibrillar portions that may be made up of granules or associated with granules, and that in many cases these fibrils are connected so as to present the appearance of a framework or network.

There is, however, another view of the structure of living matter which demands serious consideration as advanced by a most able worker in various fields of protozoan and metazoan morphology. Professor O. Bütschli, of Heidelberg, the well-known author of the comprehensive monograph on the Protozoa in Bronn's *Klassen und Ordnungen*.

As early as 1878 he advanced the opinion that the observed reticular appearance of protoplasm might be but the expression of an alveolar structure, that protoplasm has a froth-like structure. This idea he now supports by an extensive treatise and by several minor papers. In his view, living protoplasm is composed of fluid, or nearly fluid, vesicles filled with a fluid; more like an emulsion than like soapsuds. The walls of the vesicles form a framework or series of partitions that surround closed chambers. It is the optical section of these walls that gives the appearance of a network. The contents of the chambers, or alveoli, are spherules of liquid isolated from one another by the vesicle walls or enveloping layers, as are the air bubbles in a mass of froth by the pellicles of the bubbles.

This conception of the structure of protoplasm may justly claim the dignity of a theory of the structure of protoplasm, since it plausibly explains many of the observed optical appearances and also some of the activities of living matter. If an artificial mass is made having this froth-like structure it may present some of

the optical appearances of protoplasm and also in its peculiar movements simulate some of the movements of living matter, while the same physical explanation that applies to the movements of the artificial froth will, it is claimed, apply to the like movements in protoplasm.

The evidence advanced by Prof. Bütschli in support of this foam theory may be conveniently considered under the following four heads: The structure of artificial foams; the observed structure in many forms of living matter; the movements of artificial foams; the movements of protoplasm.

His artificial foam is made by thoroughly mixing in a mortar potassium carbonate with olive oil that has been heated some time. A drop of the oil lather so made is put on a glass slip, covered with a glass cover and then soaked in water; when cleared up with glycerine it is ready to observe under the microscope.

Such an artificial foam is seen under the microscope to be made up of vesicles of oil 1-5 microns in diameter and upwards. They are full of water, alkali, soap and glycerine. The whole mass of foam is fluid and flows under pressure as oil does. Drops of this foam may be kept for four to six weeks before the oil vesicles burst. Some of the characters of these foams most to be emphasized are: That drops may enlarge or diminish by the osmotic action of surrounding liquid; on the surface of a drop, as well as in the interior on surfaces of large intervesicular spaces, the minute vesicles or alveoli are arranged in a layer of small chambers quite regular in size, with their contiguous faces at right angles to the free surface (this is Bütschli's 'alveolar border'); alveoli may be arranged in radiating lines apparently by the action of diffusion currents within the drops; fibrous appearances may arise when currents elongate the alveoli so as to extend lines of them in one direction more than in others. Other properties of these remarkable compounds will be considered later in comparing them with protoplasm.

A considerable portion of the work is taken up with a well-illustrated account of the structural appearances seen in the protoplasm of a large number of different organisms. In both living and in preserved protoplasm Prof.

Bütschli demonstrates the almost universal occurrence of a network appearance similar to that caused by the oil vesicles in the artificial foams.

The methods employed consisted in: the use of Zeiss apochromatic objectives 2 mm. Ap. 1.30 and 1.40 with eye pieces 12 and 18; an iron-hæmatoxylin stain made with ferrous acetate and a $\frac{1}{2}$ % aqueous solution of hæmatoxylin; an acid hæmatoxylin made by adding acetic acid to dilute Delafield's hæmatoxylin; cutting sections one micron thick and studying them, often, in water instead of in balsam.

Though no adequate idea of this net appearance can be given without illustrations, a review of the organisms in which the author has found it may at least show the universal nature of its occurrence. Among the Protozoa the group Suctoria was examined in the representative form *Podophyra* and a meshwork found in the nucleus and in the body of the cell while alive. An alveolar layer was also seen. The group of Ciliata show the network—living *Vorticella*, *Paramœcium*, *Stylonychia*, and in the dead stalks of *Zoothamnium*. In the Flagellata living *Chilomonas*, in the Radiolaria preserved *Thalassicolla*, and in the Heliozoa living *Actinosphæria* and *Actinophrys sol* all show the reticular appearances. Amœbæ, both living and prepared, show the characteristic network appearances, while amongst the marine Rhizopods with calcareous shells, drops of viscid protoplasm crushed out from living *Miliolidae* show an alveolar border; in living *Gromia* the transition from reticular to apparently homogeneous protoplasm can be well seen in the remarkable pseudopodia.

Leaving the Protozoa, we note that in those problematical forms the *Myxomycetes*, a reticulum, as well as the important alveolar layer, are seen in small masses of *Aethalium septicum* fixed by a picrosulphuric-osmic mixture. Preserved *Pelomyxa palustris* also adds to the evidence for the reticular appearances that may be interpreted as foam structure. Among the lower plants bacteria and some *Cyanophyceæ* are claimed as presenting a nucleus-like portion with an alveolar border surrounded, in some cases, with protoplasm that presents the same net appearance.

Among the higher plants it is a noteworthy

fact that, in the cells of the stamens of *Tradescantia*, the hairs of the nettle and of *Malva*, where streaming movements of the protoplasm are known in the protoplasmic strands traversing the interior of the cells fine fibril-like structures are seen to be connected into a mesh or net even in the living cells. Does not the foam hypothesis account for these apparent networks in actively streaming protoplasm better than any other? The eggs of different animal groups show also a reticulum. In sections of the eggs of the sea urchin, *Sphærechinus*, the well known radiated appearances about the centrosomes are seen connected by transverse lines to form a network, or, as it is interpreted, a radial series of alveoli or vesicles extending in all directions from some central vesicles that form the so-called centrosome.

The red blood corpuscles of the frog show a reticulum with marked alveolar border. Networks are seen in the living cells in the branchial epithelium of *Gammarus* and in living epithelia of rotifers; also in the cells of the gizzard and foot glands of rotifers and in the epidermis of the earthworm when preserved. Sections of *Branchiobdella* show reticular appearances in the cells of the peritoneum and epidermis as well as in the cuticle itself. In the same way the cuticles of *Phascolosoma* and of *Distomum* are found to have a reticular structure like that of living protoplasm. Various tissues in the vertebrates show a reticular character; sections of the liver cells of the frog and rabbit, the epithelium of the small intestine of the rabbit, macerations of the capillaries in the spinal cord of the calf and of connective tissue in nerves of the frog. Pigment cells in the parenchyma of *Aulostomum* and ganglion cells in the earthworm and in the crayfish again show the same froth-like reticulum. Nerve fibres present special arrangements worthy of consideration; in the teased nerve of the frog there are longitudinal fibrils 6-7 microns apart connected by transverse meshes; similar appearances of elongated meshes in rows are seen in the nerves of the crayfish, rabbit and calf.

In all these cases what is actually seen is but a network appearance and not a foam structure, yet as the artificial mass that seems undoubtedly to have a foam structure presents under the

microscope the same network appearance as that seen in the protoplasm, there is a strong inference that this also is due to an actual foam. The resemblance between the appearances of the artificial foam and protoplasm is well seen in the so-called 'false networks' common to both. When fine granules of india ink are seen in water, or when fine oil drops are shaken in soda and compressed, there is formed a network of triangular meshes by the combination of diffraction rings about the separate spherules. Prof. Bütschli claims that the same 'false network' is seen in sections of liver and in other protoplasmic structures in addition to and on a higher level than the true network caused by the alveoli.

The foam theory assumes that protoplasm is in the fluid or viscid fluid state, but this requires demonstration, since many have held since the time of Brücke that protoplasm contains solid elements as part of its structure. The network is often regarded as a solid portion of the mass. The following considerations, however, tend to establish the fluid nature of protoplasm.

The vacuoles in protozoa are spherical and must hence be surrounded by fluid protoplasm. The flowing together of such vacuoles and their membrane-like envelopes are readily intelligible on the foam theory, but not if we assume that the network is a firm structure. The idea of a firm network involves that of a porous surface and the reformation of a new surface with solid supports when the mass is burst; on the foam theory the alveolar layer of closed vesicles makes the boundary of all surfaces and the laws of fluids reform this surface, however often the mass may be ruptured. The alveolar layer has no explanation on any but the fluid foam theory. This remarkable layer of chambers or vesicles is not a membrane, but a fluid layer, as may be seen in the cell division and conjugation of infusoria; yet it may in some cases be so modified as to become a membrane, or even a cuticle or chitinous shell, as in *Arcella*. The assumption of a fluid foam structure explains the radiated arrangement which the meshes of the network present around the nucleus and vacuoles. The fluid nature of protoplasm is also supported by the fact that gran-

ules occur as a rule only at the nodal points of the net, since when lamp-black is added to foam drops it collects at the nodes between the vesicles. The striated appearances of gland cells seem to indicate a fluid state and the occurrence of diffusion currents. Likewise the radiating appearances seen in dividing cells and caused by rows of meshes (alveoli) are like the lines seen in artificial foams and caused, apparently, by diffusion currents. So much do some of these striations resemble those of the artificial foam that Prof. Bütschli is led to assign diffusion currents as their cause in the case of the striations about the contractile vacuole of an amœba during diastole, and of the spindles at the poles of the spindle in caryokinesis. The striated appearances in pseudopodia and in strands of streaming protoplasm in plant cells are due to rows of elongated meshes (alveoli), and may be taken as evidence of the fluid nature of the protoplasm since they appear to be rows of vesicles stretched by tension. Similar appearances in nerve fibers offer an obstacle to the idea of the fluid state of protoplasm, for we here have permanently elongated meshes without apparent tension; if their elongation were caused by stretching in growth we would yet have to grant considerable rigidity in the lamellæ or material of the net.

Before considering the movements of foams and of protoplasm we may point out the relationship of the foam theory to those cases of apparently structureless protoplasm that remain for any theory to resolve after the actual observations have reached their limit. In the pseudopodia of *Gromia* and in the ectosarc of *Rhizopods* there are clear areas of protoplasm without granules, network or other discovered structure. Such apparently structureless protoplasm has been variously interpreted: By Heitzmann as regions where the meshwork is so stretched and attenuated as to be invisible; by Frommann as regions in which the network has become dissolved in the matrix; by Fleming as due to crowding of filaments to the point of indistinguishability, and by Leydig as masses of the hyaloplasm crept out from the framework of spongioplasm. On Bütschli's theory such areas appear structureless because the alveoli are widened with walls so stretched

as to be invisible. The thinness of the walls would make the mass physically more like a solid, and, as a matter of fact, we find such homogeneous protoplasm more rigid or viscid than the distinctly reticular internal parts in *rhizopods*.

Coming now to the movements of artificial foams as bearing upon the probable structure of protoplasm we find that such foam drops may, under favorable conditions, exhibit movements from place to place, changes in outline and certain internal currents.

The change of place may be in an extreme case as much as .45 mm. in a minute. The change of form consist in outpushings here and there that give the drop a decidedly amœboid outline that changes considerably in a few minutes' time. Of the internal currents the most interesting are the so-called 'extension currents' that pass out from the interior towards the surface, spread out over the surface and tend to return towards the point of origin. In a small drop there may be thus an axial current moving towards one end, which will be the anterior in progression, while at the other end there is a dead region where particles of india ink, if added to the foam, tend to collect in a stationary state. Such an extension current may die out and be succeeded by another with a different axis. Two drops may run together and acquire a new center of extension currents. In large drops there may be several centers of extension currents and each runs out into a pseudopodium-like outpushing of the mass. As one center of streaming dies down and another appears the outline of the large drop changes as above mentioned.

Such streaming currents may continue to exhibit themselves for a day, in one case for as many as six days. The currents are more active when the drop is heated, and electric shocks may cause change in the direction of movement, wrinkling of the surface and bursting of vesicles in the interior.

The probable explanation of these movements of the artificial foam is to be sought in the phenomena of 'superficial extension currents' that are generated whenever the surface tension of a liquid in air or in another liquid is locally diminished by bringing a spot on its surface in-

to contact with a third liquid which has a lower surface tension than the second liquid. Thus, if a drop of oil in water be brought into contact with weak alkali active currents are set up in the water and in the oil. Now, as the foam is a framework of very minute lamellæ of oil, the meshes of which are filled with a watery liquid containing potassium carbonate and potash soap, we have the conditions necessary for the formation of extension currents and streamings if alveoli burst at the surface and readjustments are made throughout the mass by the aid of diffusion currents and the bursting of internal alveoli.

Whatever the true cause of these movements in the foams their appearance is such as to suggest some of the movements of an amœba and it becomes pertinent to inquire if certain protoplasmic movements may not be the direct physical result of their assumed alveolar or foam structure. The movements of protoplasm are commonly spoken of as due to its contractility, and in an Amœba this contractility has been thought to be located either in the ectosare or in an internal framework. Many, however, have called attention to the fact that the movements of an Amœba and the streamings in a plant cell could not be explained upon any assumed contractility in an internal framework. Hofmeister referred movements of protoplasm to changes in power of imbibition and Sachs elaborated a similar idea. Englemann in 1879 assumed that his minute theoretical particles of protoplasm, inotagmas, changing their state of turgidity passed from an elongated to a spherical form and thus brought about contraction of protoplasm. As late as 1879 older views as to the participation of electrical forces in protoplasmic contraction reappeared in the papers of Felton and of Fol. Leydig, 1885, and others since then have regarded the hyaloplasma, and not the framework, as the essential motile substance.

Surface tension as an element in protoplasmic movements was brought in by Berthold, in 1886, in explaining the streamings in plant cells; while Quincke, in 1888, explained such movements on the basis of extension currents caused by surface tension. Though Quincke's conception of the structure of the plant cell was quite

unlike what has been observed his application of surface tension and of extension currents served as an introduction for Bütschli's explanation of protoplasmic movements.

Professor Bütschli attempts to explain some of the more simple forms of amœboid movement as results of the foam-like structure of protoplasm, and thinks surface tension and extension currents are the essential factors. The axial stream which is found in many Amœbæ passing towards the progressing anterior end to bend and flow back near the surface of the animal is, he thinks, an extension current. The chief differences that he sees between such axial streams and the extension currents in artificial foam is that they endure but a short time and flow back but a short distance in the Amœba. The conditions present in protoplasm may be such as to form extension currents, for, as we assume it to be a framework of liquid not soluble in water enclosing water containing substances in solution, we may suppose changes in surface tension would set up such currents as they do in the manufactured foam drops. There is some evidence that the watery parts of protoplasm are alkaline and it is also probable that fatty compounds may be present in the framework. The bursting of some alveoli at the surface would pour out on to the surface some of the watery contents which will cause a local diminution in surface tension and thus give rise to an extension current. In this way, also, pseudopodia may be formed, here and there, by local extension currents.

This explanation, however, cannot be applied to the formation of the remarkable anastomosing pseudopodia of many Rhizopods, and even where it seems to apply it meets with a severe rebuff in the results of experiments upon *Pelomyxa*. It was found that india ink in the water about a crawling *Pelomyxa* shows currents the reverse of what they are about a drop of liquid exhibiting extension currents, so that the assumption of this simple physical explanation for the movements in an Amœba seems on a very weak footing.

The author, however, thinks that in some way the extension current may perhaps be applied to the explanation of rotation movements in the protoplasm of plants cells, and that even

muscular contraction may be explained along similar lines. On the foam theory the muscle is made up of a mass of polygonal vesicles; if there be chemical changes in the watery contents of many of these in one plane the corresponding changes in surface tension of the walls or lamellæ will produce changes in shape of these polygons, and in the mass a shortening and thickening or muscular contraction!

But all motions are not of this nature, since the movements of certain granules seem to be automatic and not, as is often assumed, merely passive. Yet even these granules may in turn serve to change the surface tension of the lamellæ, and so ultimately contribute to readjustment throughout the mass.

In conclusion we may venture to affirm that the foam theory at present falls short of a physical explanation of any of the activities of protoplasm, yet as an approximation to what may well prove to be the actual structure of protoplasm it cannot be too highly praised.

E. A. ANDREWS.

The Structure of Man. An Index to His Past History. By DR. R. WIEDERSHEIM, Professor in the University of Freiburg in Baden. Translated by H. and M. Bernard. The Translation edited and annotated and a Preface written by G. B. Howes, F. L. S., Professor of Zoölogy, Royal College of Science, London. With 105 Figures in the Text. Macmillan & Co., London and New York. Price \$2.60.

This is an excellent book and should be in the hands of all students of anatomy. We have had in the writings of Huxley, Vogt, Darwin and Hækel dissertations on the position of man in relation to the lower animals, but no book has appeared so comprehensive in scope, yet so minute in details, as the one before us. It originally appeared in German in 1887, as an academic treatise under the title, '*Der Bau der Menschen.*' The present volume is a translation of the revised and enlarged second edition. The author states that he has prepared it especially for the lay reader, and the editor suggests in the preface that it may be of use to the medical student while engaged in the study of anatomy. The distinguished professor of Freiburg has many admirers in this country, and

this book with the notable additions by the English editor will be made welcome. The following comments are made in no spirit of unkindly criticism. In the 228 pages there occur 235 citations of authors. Many of the statements are without reference, and even when journal or volume is given no uniform plan is pursued, and, often, the year of publication is omitted. The value of this display of learning when the objects of the book are recalled, does not always appear. Prof. Howes has given his numerous citations in bracketed paragraphs. Most of them are from English sources. One would suppose from statements in the preface that *Pithecanthropus* had been discussed by none but British anatomists. Throughout the book French and Italian writers receive little consideration. There is scant allusion to Albrecht, and, so far as we have seen, none to Sutton. No reference is made to the admirable essay of Dr. Frank Baker on the 'Ascent of Man.' Certainly these three writers have contributed in a notable manner to the subject embraced in the general thesis. The value of the writings of other Americans could never be determined by this book. On the homologies of the cusps of the mammalian teeth Röse is followed by Wiedersheim, Forsyth Major by the editor, while Cope, Osborn and Scott shift vaguely across the scene. We note that while the book is designed for medical students and lay readers the relations of vestigial structures to the initiation of morbid processes is not emphasized. The connection between the morphology of the vermiform appendix and the frequency with which this structure becomes a factor in disease is not mentioned. The relation existing between the apex of the lung in the region of the neck and the restriction of rib-protection at this place is dwelt on, but the next and, to our minds, the inevitable step, namely, to account for tubercular deposits in the lung apex by the same statement of facts is not even alluded to. The structure of man cannot be logically separated from the manner in which diseased action is manifested in that structure.

It is curious that from the great wealth of material illustrating atavism in the skull that the author should make nine references to the work by the cousins Sarasin on the Ceylon Ved-

dahs. This is liberal, when it is recalled that these writers confine their observations to thirty-three skulls and a few skeletons.

HARRISON ALLEN.

Evolution in Art, as Illustrated by the Life Histories of Designs. By ALFRED C. HADDON, Professor of Zoölogy in the Royal College of Sciences, Dublin, etc. With 8 plates and 130 figures. 1 vol. 8vo. pp. 364. Price 6 sh. (London, Walter Scott, Ltd. 1895.)

Prof. Haddon is already well and favorably known to students both of art and ethnology by his admirable monograph on 'The Decorative Art of British New Guinea,' published in 1894 by the Royal Irish Academy. The present work may be looked upon as a development of that monograph, extending the principles it embodied to a much wider range of art concepts. He takes, indeed, in his opening chapter the decorative art of New Guinea as an example of the method of study of art in general.

The main body of the book is devoted to the discussion of two questions: 1, the material of which patterns are made, and, 2, the reasons for which objects are decorated. Under the first of these, he points out that the originals of decorative art designs are mainly either natural or artificial objects. For the latter, he adopts the term suggested by Dr. H. C. March, 'skeuomorphs,' from a Greek word signifying utensils, etc.; the former he divides into 'physicomorphs, biomorphs and heteromorphs.' He portrays with a large range of illustration how these objective originals became transferred into æsthetic conceptions, and at times conventionalized quite out of recognition, were we ignorant of the intervening steps.

The reasons for which objects are decorated the author considers to be mainly for the sake of information (scenes, picture writing, etc.) for the love of art itself, for the desire to display wealth and for magic and religion. He gives, among these, but a small field to 'art for art's sake'—if, indeed, any, among primitive people. Yet he does not fail to recognize, what some writers have overlooked, that the æsthetic sentiments are the real and only source of all art products, no matter what else they subserve.

The work closes with a suggestive chapter on

the 'scientific method of studying decorative art,' which deserves the attentive study of all interested either in the history of art or in ethnology. It would be difficult to point to a more satisfactory statement of the subject.

D. G. BRINTON.

The Hill Caves of Yucatan. By HENRY C. MERCER. Philadelphia, J. B. Lippincott Co. 1896. 1 vol., 8vo. Illustrated. Pp. 184. Price, \$2.00.

The sub-title to this book explains its aim with sufficient fullness—'A search for evidence of man's antiquity in the caverns of Central America: being an account of the Corwith expedition of the department of archaeology and paleontology of the University of Pennsylvania.' Through the generosity of Mr. Corwith this expedition was fitted out and its results were destined to enrich the institution named. A competent corps of explorers under the direction of Mr. Mercer proceeded to Yucatan last February and examined a large number of caves in the low range of mountains which trends from northwest to southeast, about thirty miles south of Merida. In this immediate vicinity are situated the famous ruined cities of Uxmal, Mani, Mayapan and others. There, if anywhere, we might reasonably expect to find traces of the early art of the natives and the record of the evolution of their culture, if it was developed in the peninsula.

This would be the more certain to be the case on account of a peculiarity of the caves of Yucatan. In many portions, during the dry season, the only sources of the water supply are the springs and basins in these caves; therefore, under present conditions, from the first arrival of man he must have resorted to them daily for months at certain periods. He could not fail to have taken with him and to have left some traces of his visits, stone implements, broken pottery, bones, ashes and charcoal from his fires and the like.

Taking these facts as his guides, Mr. Mercer examined, with the most scrupulous care, layer after layer in several of the most notable caverns which were also sources of water supply. The excavations were conducted under his personal superintendence and every sign of man's

presence and every bone were noted as soon as taken from their sites. In this manner he examined twenty-nine caves, six of which yielded valuable results.

His conclusion from this arduous and extended investigation is that there is no trace of any older or more primitive human visitors to the peninsula than the Mayas in about the stage of culture in which they first became known to the Spaniards.

The animal bones and shells which the expedition brought back were examined by specialists and all proved to belong to existing species. Like the remains of man, there was nothing in them to hint at a great antiquity. This fact, however, suggests that the caves themselves must be of quite modern formation; so, perhaps, the expedition was after all looking in places where it is not possible to find the relics of 'palæolithic' man if they actually are in the peninsula. We cannot, therefore, unreservedly accept the author's dictum (p. 177), 'no earlier inhabitant had preceded the builders of the ruined cities in Yucatan.'

The narrative portion of the volume are pleasantly composed, enlivened not only by an ever-present enthusiasm for the main object, but touched in frequent passages with a quick appreciation of the strange and the beautiful in nature and the odd and humorous in life. Whether archæologist or not, the reader will pass agreeable hours over Mr. Mercer's pages.

Some little criticism must be added on the author's capricious orthography of Maya words. The recognized authority is the dictionary of Pio Perez. That work admits no *s* in the Maya alphabet; but Mr. Mercer employs it freely, as *sitz* for *tzitz*, *spukil* for *xpukil*, *sac* for *zac*, thus confounding three different sounds in one. At other times his forms are incorrect, as *tzat-un-tzat* for *zataan zat*, *coyok* for *cooch*, etc. This occurs also in the Spanish, where he gives *volan* for *volante*, the name of a vehicle. The translations of some of the Maya terms are dubious, but for these he does not assume responsibility.

These, however, are slight blemishes, and the book, with its handsome illustrations, excellent paper and attractive account of travel and exploration, is sure to entertain and instruct every reader.

D. G. BRINTON.

Chemical Experiments Prepared to Accompany Remsen's 'Introduction to the Study of Chemistry.' By IRA REMSEN and WYATT W. RANDALL. New York, Henry Holt & Co. 1895. Price 50 cents.

In this edition of Prof. Remsen's laboratory manual a number of new experiments have been introduced, and the course of study as now arranged covers pretty fully the ground outlined by the Committee on Secondary School Studies of the National Educational Association. Like all of Prof. Remsen's text-books this one is characterized by clearness and precision of statement. The directions for each of the laboratory experiments are carefully worded, and it is difficult to see how students in following them could possibly fail in getting good results.

The course begins with experiments which show the difference between chemical and physical phenomena, then the characteristic properties of chemical compounds as distinguished from mechanical mixtures are studied, and this leads on to a systematic study of the preparation and properties of the more important non-metallic and metallic elements. At the end of the book there is a brief introduction to the methods of qualitative analysis. Two quantitative experiments requiring the student to work with accurate weighing and measuring instruments are given; one of these is the determination of the percentage of oxygen in potassium chlorate, the other the determination of the equivalent of zinc. Nothing serves so well as a few experiments of this kind to impress upon students the significance of the fundamental laws of chemistry. Nearly every one of the laboratory directions is followed by a series of questions, the object of which is to make students think about their work, and to lead them on to draw conclusions from the results that they have obtained. There are no blank pages in the book, and it is expected that a full record of each experiment and the conclusions that have been drawn from it be kept by the student in a separate note-book, and that this note-book be submitted to the teacher from time to time for revision. Another excellent feature is that at the beginning of the directions for each experiment there is a list of all the apparatus and chemicals required for the work.

Students who follow the course of study given in this manual will have a most excellent introduction to chemistry, and teachers in arranging the work for their classes cannot go far astray if they are guided by the experience of one who has been preëminently successful in this line of work.

E. H. KEISER.

SOCIETIES AND ACADEMIES.

BOSTON SOCIETY OF NATURAL HISTORY.

THE Society met November 20; eighty-four persons present. Dr. J. Walter Fewkes, in his paper, 'Some newly discovered Cliff ruins in Arizona,' described, and illustrated with stereopticon views, the early home of the Moquis. The ruins studied were of three types: First, the cave dwellings situated on high bluffs and consisting of series of chambers hewn out with stone implements—these chambers have paved floors but the walls show no trace of masonry; secondly, stone houses built surrounding large crater-like depressions; and, thirdly, two large cliff ruins situated many miles north of Montezuma's Well.

The larger of these two ruins, affording room for 500 people, was four stories in height, with floors supported by beams of pine or cedar. Excavations revealed remnants of cotton cloth, blankets made of feathers, pottery, baskets and ropes made of fibers of century plant. Skeletons found beneath the floors showed the burial customs, and the abundance of stone implements with the absence of metal seemed to prove that the workers belonged to the stone age. The walls covered with symbols, practically identical with those now found in the Moqui houses, gave evidence of formal worship. The second ruin, smaller but better preserved than the first, showed the impressions of the hands of the workmen made at the time of plastering the walls of the rooms; a quantity of corn in the ear was found beneath the floor of this ruin. The cliff houses were probably abandoned before the discovery of the country by the Spaniard, and there is no evidence that the cliff dwellers were a distinct people.

The Society held a regular meeting December 4; eighty-one persons present.

Mr. L. S. Griswold discussed some geographical and geological features of the San Francisco Mountains and the Grand Canyon of the Colorado, describing in some detail the petrified forests. The paper was illustrated by a series of lantern slides.

SAMUEL HENSHAW,
Secretary.

NEW YORK ACADEMY OF SCIENCES.

THE regular business meeting was called to order December 2, 1895.

Prof. N. L. Britton presented the report of the Committee on the Audubon Monument and asked that the committee be discharged. He reported the satisfactory completion of the monument and the placing of the new die, which is guaranteed for at least two years. He announced that after all the expenses of the monument had been paid a balance of \$1,797.25 remained on hand, which the committee therewith turned over to the treasurer of the Academy, together with the following resolution:

Resolved, That after all bills incurred by the committee shall have been paid, the Secretary and Treasurer shall pay over the balance to the Treasurer of the Academy, under the title, 'Audubon Publication Fund,' the interest of which shall be annually devoted to the publication of a memoir on some zoological or botanical topic, if a paper suitable for such memoir shall be presented. If no such paper shall be presented during any one year, the interest shall be allowed to accumulate until one is presented. Memoirs published by this fund shall be so designated."

A committee was appointed to audit the accounts of the report.

The Section in Astronomy and Physics then organized, with Prof. Woodward in the chair.

The first paper was by Prof. Harold Jacoby, on 'The Determination of Division Errors in Straight Scales.' The author only read the introduction to the paper and outlined the method. Thereupon, with the permission of the chairman, he read an historical description of the observatory at the Cape of Good Hope.

The second paper was by C. A. Post, on 'Photographs of the Lunar Eclipse of September 3, 1895.' The photographs exhibited were

very beautiful and brought out some interesting points with reference to time of exposure.

The third paper of the evening was by Prof. J. K. Rees, on 'Drawings made by Percival Lowell of the Markings on the Planet Mars.' These drawings corroborate to a very remarkable degree the observations of Schiaparelli.

and indicating the manner in which poisoning is likely to occur. The classification of the poisoning agents is indicated by the appended table. The paper will be printed in full in *The Alumni Journal* of the College of Pharmacy.

H. H. RUSBY,
Recording Secretary.

TABLE EXHIBITING THE POISONOUS PLANTS OF THE VICINITY OF NEW YORK CITY.

	ROOTS, ETC.	BARKS.	HERBAGE AND LEAVES.	FLOWERS.	FRUITS AND SEEDS.
Known powerful poisons liable to occasion accidents.	Phytolacca. Robinia. Cicuta. Sambucus. Solanum tub. (some tubers.) Veratrum. Convallaria.	Robinia. Sambucus.	Cicuta. Tanacetum. Datura. Veratrum. Aconitum. Nicotiana.	Convallaria.	The Actæas. Cicuta. Conium. Solanum tub. " dul. Datura. Taxus. Ricinus.
Known powerful poisons not liable to occasion accidents.	Aconitum. Podophyllum. Sanguinaria. Chelidonium. Iris. Leptandra. Arisæma.		Ranunculus. Clematis. Prunus. Lobelia inf. Absinthium. Convallaria. Hyoscyamus. Atropa. Solanum nig.	Sambucus. Conium. Cannabis. Juniperus, etc. Taxus. Chelidonium.	Aesculus Pavia. Chenopodium amb. Euphorbia. Hyoscyamus. Atropa.
Known to be poisonous in minor degree.	Cimicifuga. Actæa. Nasturtium Arm. Viola. Gillenia. Triosteum. Ipomœa pand. Apocynum. Euphorbia Ip. Trillium. Asclepias.		Nasturtium pal. Viola. Menyanthes. Kalmia. Pieris.	Sambucus. Kalmia. Pieris.	Sambucus. Sinapis. Juniperus.
Suspicious.	Ailanthus. Kalmia. Pieris. Ledum. Rhododendron. Lachnanthes. Tephrosia.	Ailanthus. Kalmia. Ledum. Pieris. Rhododendron. Prunus. Taxus.	Ailanthus. Lobelia card. " syph. Linaria. Robinia. Chenopodium. Phytolacca. Rhododendron.	Robinia.	Podophyllum. Ailanthus. Aesculus Hip. Prunus.

The drawings provoked an animated discussion in which Profs. Mayer, Rees, Post, Jacoby and Hallock took part. The prevailing opinion seemed to be that, although Mr. Lowell deserved much credit for great application and labor, we must await further corroboration before accepting his rather extreme theories.

WILLIAM HALLOCK,
Secretary of Section.

THE TORREY BOTANICAL CLUB.

At the meeting on Wednesday evening, November 27, a lecture was delivered by the undersigned on *The Poisonous Plants of the Vicinity of New York City*, illustrated by colored lantern slides. The subject was treated with special reference to the presentation of evidence proving the poisonous nature of the plants named

GEOLOGICAL CONFERENCE OF HARVARD UNIVERSITY, DECEMBER 3, 1895.

Some Features of Joints. By J. B. WOODWORTH. For several years past the author has been gathering material illustrating the intimate structure of joint-planes. Observations based upon the closely-set joint-planes of the argillites of the Mystic river quarries, near Cambridge, show that there is a type of joint-plane exhibiting on its surface fine divergent lines comparable to the 'percussion rays' of flint chips, and indicating the direction of propagation of the splitting movement which resulted in the formation of the joint. These lines were in the case of the joints, called 'feather fracture.' These apparent rays are simply cross fractures between thin laminæ of rocks formed by minute planes of fracture, and some of the typical joint-planes

are made up of combinations of these small joint-planes and the cross fractures. (See Figs. 1 and 2.)

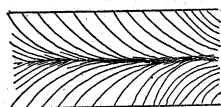


Fig. 1. Feather fracture. The lines diverge towards the margin of the divisional plane.

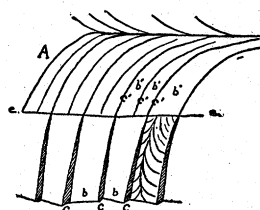


Fig. 2. Ideal arrangement of planes and fractured surfaces. A, principal joint-face; e, e, margin of A; b, b, imbricated planes of fringe; c, c, fractured surface between b-planes; b' b' and c' c', analogous to bb and cc on A, giving rise to feather fracture. In the b-plane on the right feather fracture is also shown.

The margin of joint-planes of this class frequently dies out in a fringe in which these small joints are much enlarged, the interval between them is increased, and this is accomplished by their being turned at a considerable angle, from 10 to 25 degrees, to the principal joint-plane. These small joints also, where well developed, show feather fracture lines diverging towards the outer margin. Joint-planes are thus complex surfaces of fracture. Over the surface of the large joints the smaller joint-planes become so closely set and so nearly parallel to the principal surface of fracture that these smaller fracture surfaces gradually disappear before the unaided eye and become a mere granulation of the joint surface.

Where these joints are developed in a single stratum, they are commonly in the Mystic River argillite quarries in the form of elongated elliptical planes, the main fracture dying out above and below where the texture of the rock changes parallel with the stratification plane. The fringe of marginal joints then give rise to a set of joints in the underlying and overlying beds having a different direction from that of

the main joint in the intermediate bed. Of less frequent occurrence are discoidal joints, evidently entire joint planes, of small size and circular in area because the stress which produced them was relieved by a small fracture in essentially homogeneous material. These vary

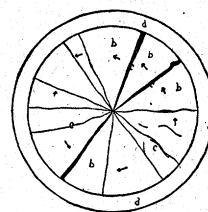


FIG. 3. Discoidal joint, with b-planes and c-fractures analogous to system of fractures in fringe of elliptical joints; d, marginal conchoidal fracture area. Arrows show dip of imbricated b-planes.

from half an inch to three inches in diameter. They consist of the small imbricated planes (b in the diagram) and the cross fractures (c in the figure). The author refrained at the present stage of the investigation from expressing an opinion as to the origin of these joints. The subject was illustrated by typical specimens. These joint structures also occur in the felsites of Salem Harbor, the granitic and dike rocks and in gneisses. A report on the investigation is in preparation.

T. A. JAGGAR, JR.,

Recording Secretary.

NEW BOOKS.

The Cambridge Natural History, Vol. V. Peripatus, ADAM SEDGWICK; *Myriapods*, F. G. SINCLAIR; *Insects*, DAVID SHARP. London and New York, Macmillan & Co. 1895. Pp. xi + 584. \$4.00.

Text-book of the Embryology of Invertebrates. E. KORSCHOLT and K. HEIDER. Translated from the German by Edward L. Mark and W. McM. Woodworth. London and New York, Macmillan & Co. 1895. Pp. xv + 484. \$4.00.

Die Spiele der Thiere. KARL GROOS. Jena, Gustav Fischer. 1896. Pp. xvi + 359. M. 6.

Grundzüge der Marinen Tiergeographie. ARNOLD E. ORTMANN. Jena, Gustav Fischer. 1896. Pp. iv + 96. M. 2.50.